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OXIDANT AIR POLLUTANT EFFECTS ON A WESTERN CONIFEROUS FOREST ECOSYSTEM TASK B. HISTORICAL BACKGROUND AND PROPOSED SYSTEMS STUDY OF THE SAN BERNARDINO MOUNTAIN AREA

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Prepared for:

Environmental Protection Agency

January 1973

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PB 228 332

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WESTERN CONIFEROUS FOREST ECOSYSTEM

Task B

Historical Background and Proposed Systems Study of the San Bernardino Mountain Area

JAN 1973

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OXIDANT AIR POLLUTANT EFFECTS ON A WESTERN CONIFEROUS FOREST ECOSYSTEM

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OXIDANT AIR POLLUTANT EFFECTS ON A
WESTERN CONIFEROUS FOREST ECOSYSTEM

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Summary

Physical characteristics of the San Bernardino Mountains, i.e. geology, topography, soils, hydrology, and climate are described in the following report. Histories of the vegetation, vertebrate and arthropod populations and human activity are also included to illustrate the evolutionary changes of modern times. An attempt has been made to superimpose the known and suspected influences of oxidant air pollution on this already complex mosaic of physical and biological factors. Finally, the available knowledge of techniques needed to develop an elaborate conceptual model of the forest ecosystem are presented and discussed.

Essentially, all of the recent air pollutant research has been concerned with direct effects of oxidants on a few plant species, principally ponderosa and Jeffrey pine. These two species dominate a majority of stands in the San Bernardino Mountains and thus are responsible for the present structure which has special esthetic qualities valuable to recreationists and the integrity of the present ecosystem.

Strongly discipline-oriented information about the forest system, e.g. soils characteristics, meteorological phenomena, tree physiology, etc. has been produced by most of the previous investigations. Other studies, directed towards community biology, have described the various constituents of the system in qualitative, and sometimes quantitative terms. Both approaches may have spatial information incorporated into the studies. However, the interactions among components, information necessary to

operate a dynamic model of the system, are poorly identified and have received little scientific attention since they require more than simply an enumeration of the components of the system.

Future studies should be directed towards the establishment of life tables for ponderosa and Jeffrey pine as well as other associated species. This approach will establish relative importance of the direct effect of oxidant air pollutants and the various biotic and abiotic agents as mortality factors during each stage of the life cycle from flowering and anthesis through the intermediate size or age classes up to the mature tree. Construction of life tables will provide the core data needed for the modeling process and associated studies will begin to describe the indirect effects or reverberations in the ecosystem which are caused by oxidant air pollutants.

A large group of professional scientists who consulted together about the ecology of smog in this forest system, had several recommendations emerge from their observations.

It was acknowledged that there are many more components in the system than can be studied adequately. The scientists felt that past studies have adequately identified only a few of the principal components in the system since many of these are probably the emergent properties of interactions which simply have not been studied. They believe that time is of the essence in attempting to discover the important operating factors in the system. Recent observations indicate an accelerating rate of air pollutant damage. There was serious concern that continued deterioration of the forest ecosystem may reach a point at which there is no longer an ability to recover, and that the changes observed would permanently modify the system, very possibly in an undesirable manner. Vegetation and its dynamics were considered to be the principal objects of concern. The major tree species should receive much greater attention than they have in the past, and this attention should be focused on the life history dynamics of the principal conifers and hardwoods. Parallel with these studies, major efforts should begin in order to understand the roles of predators (herbivores) and parasites (pathologic organisms) in the life history of the major vegetation.

Finally, the scientists involved in this review consider it necessary to develop an elaborate conceptual model ofthis system based on what needs to be known in order to describe its dynamics and to provide an opportunity to intelligently manipulate (manage) it, both through simulation techniques and on the ground. There was strong agreement that the development of this model was an integral part of any system's research done on the San Bernardino National Forest. They cautioned that the model must conceptualize the system in such a manner that its complexity can be analyzed, rather than to proceed to simplify the real features of the system prematurely and thus lose the opportunity to investigate that complexity.

Appendix to Summary

More detailed observations about needs, and recommendations can be found on the following pages of the Task B report:

Vegetation: pp. 35-36
Vertebrates: p. 12
Arthropods: pp. 2, 4-7, 9-10, 12, 14-17
Meteorology: p. 14
Soils: see R. Arkley's "Research Needs", 2 pp.
Sociology: p. 10-18, 20, 22-26

INTRODUCTION

Extensive urban development and industrial growth in the South-coastal basin of California during the past three decades has caused an alarming increase in air pollutants. Reactive hydrocarbons and nitrogen oxides, precursors of oxidant pollutants, are generated in large quantities during combustion of petroleum fuels to meet the energy demands of a growing population.

Ozone and peroxyacetyl nitrate (PAN) are two of the most damaging pollutants in the complex mixture known popularly as "smog" or photochemical oxidant air pollution. These agents which cause serious damage to plants, animals and humans are formed in the atmosphere above urban areas when nitrogen dioxide and hydrocarbons react in the presence of sunlight. Local weather provides both the means of concentrating the contaminants e.g., the temperature inversion, and lateral air movement or delivery system which can transport heavily polluted air up to 80 miles downwind.

In the Southcoast air basin, oxidant air pollutants have increased phenomenally since the mid-1940's affecting broader and broader areas. Similar increases have been witnessed in other large urban areas of California and in other states. Very often the downwind areas typically agricultural or mountainous with forests and other valuable wildland vegetation receive longer durations of exposure to heavy pollution than the urban source area.

The mixed conifer forests of the Angeles and San Bernardino National Forests, the extensive citrus and wine grape plantings and many acres of vegetable crops - all downwind from the Los Angeles metropolitan area -

have provided mute testimony of the serious damage by ozone and PAN. Losses of agricultural crops have been estimated in the millions of dollars annually and many sensitive crops can no longer be grown profitably.

In the local National Forests, sensitive species such as ponderosa pine began to show injury in the early 1950's. Severely pollutant-injured trees are made dangerously susceptible to the pine bark beetle which quickly kills trees outright. The result of moderate to severe oxidant damage to nearly 100,000 acres of the total of 160,000 acres of mixed conifer type in the San Bernardino National Forest has been the need to select or salvage cut some management units as often as three times in ten years to remove bark beetle susceptible trees.

The effects of air pollutant damage to the forest cannot be estimated in terms of timber volume or dollars because the principal use of the forest is for the various recreational pursuits of the nearly 12 million people who live within two hours drive. Forest managers seek first to enhance the visual properties of the landscape and to increase the quality of the visitor's recreation experience.

In the mixed conifer forests of the western Sierra Nevada Mountains where oxidant damage is just beginning to be evaluated, both timber and recreational values are at stake.

Beyond the visible deterioration of several key species of the mixed conifer forest, what additional events may be shaping up which may profoundly affect all elements of this ecosystem? What are the important interactions between plants, animals and their physical environment which will determine the future state of the system? We do not have answers to these questions and cannot answer them with independent, highly fragmented, short-term research efforts. A highly integrated systems approach using many research disciplines will be required to determine the future state of the mixed conifer forest of the San Bernardino mountains. An understanding of successional trends of vegetation and the subsequent effects on arthropods, birds, animals and people can have these foreseeable benefits:

1. information for forest management.
2. upgrading, secondary standards for air quality.
3. providing a method for doing a systems study on other conifer forests threatened by pollution.
4. provide information to inform the public of the need for their support in controlling air pollution sources.

The following report includes detailed historical information about the biological and physical characteristics of the forested area proposed for the interdisciplinary investigation of air pollutant impact and concludes with suggestions for an integrated systems study designed to prepare a predictive model.

Vegetation Committee Report
History and Suggested Protocol
for
Environmental Protection Agency

Study of the Impact of Oxidant Air Pollution on the Mixed Conifer Forest Ecosystem

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INTRODUCTION

Green vegetation is the most important element of the biological community because it captures and stores solar energy and releases oxygen. The other members of the community, i.e. herbivores, carnivores, and decomposer organisms are completely dependent on green vegetation--the "producer". This guiding principle underscores the importance of healthy vegetation as a "stablilizer" of organization among the communities of organisms in their controlling physical environment. An understanding of the changes in the plant communities suffering chronic air pollution injury is vitally necessary to predict the fate of the ecosystem.

This section describes the plant communities of the San Bernardino Mountains and the suceessional trends which have determined community composition in elevational zones prior to the influence of photochemical oxidant air pollution. Emphasis has been placed on information, largely unpublished, which pertains directly to this mountain range and its vegetation history. Extrapolation of information from the abundant literature on similar vegetation types in the forests of the Sierra Nevada has been purposely limited because of the absence there of the distinct marine influence experienced in the San Bernardino Mountains.

We are indebted to the self-made botanist Samuel B. Parish who lived in San Bernardino from 1872 until after the turn of the century for many written works (1894, 1917) on the vegetation of the mountains during that time. John B. Leiberg (1897-98) surveyed the San Bernardino Mountains to determine the acreage of merchantable timber and also recorded the condition and species composition of the forest in several elevational zones on both the northern and southern slopes of the range. Also, much useful information about the appearance of the virgin forest, pioneer lumbering, fires, floods, and land development (1769-1930) are recorded in a very comprehensive history: "Saga of the San Bernardinos" by La Fuze (1971).

Finally, this section discusses the current knowledge of both the direct and indirect effects of photochemical oxidant air pollution particularly ozone on the vegetation of the conifer forest and woodland chaparral zones. Specific recommendations are made for future research which is necessary to understand the full impact of oxidant in the ecosystem.

Vegetation Zones and Types

The vegetation of the San Bernardino Mountains is composed about equally of chaparral and forest types with important minor elements of woodland, sagebrush, and grassland. Horton (1960) and Minnich (1969) have undertaken major treatments of this vegetation. Horton (1960) recognized six vegetation zones on the basis of plant physiognomy and environmental conditions (Fig. A1): chamise-chaparral, woodland-chaparral, desert chaparral, Pinyon-Juniper woodland, timberland chaparral, and coniferous forest. One or more vegetation types occur within each zone. Twenty of these types were defined by Horton (1960) on the basis of field reconnaissance. Minnich (1969), using infrared color imagery on aerial photographs, mapped 28 vegetation types in the San Bernardino Mountains (Fig. A2). The relationship between the vegetation types recognized by the two authors is indicated in Table A1. A brief description, based on Horton (1960), of each vegetation zone follows.

The Chamise-Chaparral Zone is characterized by a scrub vegetation which varies in species composition and stand density. Chamise (Adenostoma fasciculatum) is the most common species herein. This zone is distributed from near sea level to 3,500 to 5,000 feet on north-facing slopes and to 4,500 to 5,500 feet on south-facing slopes (Fig. A1). Within this range, annual precipitation varies from 13 to 35 inches. Fire occurs frequently and has been a primary factor in the evolution of the vegetation. Five major vegetation types are found in the chamise-chaparral zone: (1) pure chamise-chaparral, (2) chamise-ceanothus chaparral, (3) chamise-manzanita chaparral, (4) scrub oak chaparral, and (5) coastal sagebrush. The important species in each of these types are listed in table AI. The vegetation of the chamise-chaparral zone has been studied by a number of investigators. Comprehensive papers include those of Cooper (1922), Miller, E. H., Jr. (1947), and Navek (1967).

The Woodland-Chaparral Zone is located on the coastal side of the mountains and to a limited extent in the Mojave River drainages (Fig. A1). It is characterized by chaparral and woodland types dominated by oaks and by localized stands of big-cone Douglas-fir and knobcone pine. On north-facing slopes, the zone may begin at elevations of 3,500 to 5,000 feet and extend to 5,000 or 6,500 feet. The lower altitudinal range on south-facing slopes is from 4,500 to 5,500 feet while the upper altitudinal range is from 6,000 to 7,500 feet. Precipitation ranges from 22 to 45 inches a year. As in the chamise-chaparral zone, fire is common. Live oak chaparral, live oak woodland, big-cone Douglas fir forest, knobcone pine forest, and coulter pine forest are the major vegetation types in the zone (Table A1). Wright (1966, 1968) has examined the distribution of knobcone pine and coulter pine within the woodland-chaparral zone.

The Desert Chaparral Zone is characterized by open scrub vegetation. Usually one-half or more of the soil surface is exposed and unprotected by the shrubs. The zone occurs in the Mojave River drainages and the Cajon Pass area (Fig. A1) and is generally found at elevations of 3,800 to 7,500 feet. In this range, precipitation averages 12 to 25 inches annually.

Fire is rare in this zone because of the open cover, but the common species usually recover following burning in the same manner as the shrubs in the chamise-chaparral and woodland-chaparral zones. The single vegetation type in this zone is the desert chaparral (Table AI). Hanes (1971) discusses this type in his treatment of succession in the chaparral of southern California.

The Pinyon-Juniper Woodland Zone is principally located in Deep Creek and in the vicinity of Big Bear Lake (Fig. A1). The zone contains woodland and scrub vegetation in which Great Basin Sagebrush (*Artemisia tridentata*) is found. The woodlands are generally open with over half of the soil surface exposed. The notable exception to this open character is the occasional dense stands of Juniper (*Juniperus occidentalis*). This zone ranges in elevation from 3,000 to 9,000 feet with average annual precipitation of 10 to 30 inches. Wildfires are not common.

Minnich (1969) recognized six vegetation types (Western Juniper-Mountain Mahogany Woodland, Pinyon Pine Woodland, Pinyon-Juniper Woodland, Great Basin Sagebrush, Joshua Tree Woodland, and Juniper-Joshua Tree Woodland) in this zone while Horton (1960) divided the zone into two major types (Pinyon-Juniper Woodland and Great Basin Sagebrush).

The Timberland Chaparral Zone is characterized by a scrub vegetation usually under 4 feet in height and may be open or very dense. Timberland chaparral occurs throughout the higher mountains (5,000 to 11,000 feet) and shows its best development in the eastern portion of the San Bernardino Mountains (Fig. A1). The average annual precipitation varies from 30 to 45 inches most of which occurs in the form of snow. Summer wildfires are common and are considered a principle factor in the maintenance of the type. A single major vegetation type occurs in the zone--timberland chaparral (Table AI).

The Coniferous Forest Zone is found throughout the San Gabriel and San Bernardino Mountains (Fig. A1). It ranges in elevation from 5,000 to 6,500 feet on north-facing slopes and 6,000 to 7,500 feet on south-facing slopes upwards to the highest peaks (San Gorgonio, 11,502 feet). These forests vary in both stature and density according to vegetation types and environmental conditions. At middle elevations, the stands of ponderosa pine-white fir forest are usually dense and the height of trees will average 100 feet or more. At higher elevations a Krummholz type is found where the widely spaced trees are so stunted as to resemble shrubs. The precipitation is largely in the form of snow and ranges from 25 to 50 inches a year. Fires are common but the area burned recently is usually small except where major fires driven by high winds spread from chaparral areas into the forest.

Several vegetation types are found in the coniferous forest zone. Horton (1960) recognized seven types (pine forest, ponderosa pine-white fir forest, sugar pine-white fir forest, grassland, black oak woodland, alpine forest, barren areas). Minnich (1969) defined eight types in the zone on the basis of imagery on color infrared aerial photographs. Using this method, he was not able to distinguish the different coniferous forest types recognized by Horton's (1960) ground reconnaissance. A comparison of the types recognized by both Horton (1960) and Minnich (1969) is found in Table AI.

Plant Succession in the San Bernardino Mountains

Plant succession is the naturally occurring change in vegetation types involving a series of replacements of one type by another until a steady state is reached. The vegetation type occurring in the steady state is able to replace itself and is known as the climax. The climax is in equilibrium with the dominant environmental conditions in an area.

In most cases, the climate of an area is the determining factor in the development of the climax. However, within a climatic zone other conditions may be more important in controlling plant succession. The terms climatic climax, edaphic climax, and fire climax designate climax types controlled by specific factors. Within a broad regional area, such as the San Bernardino Mountains, several different climaxes will occur because of the variations in environmental conditions. At some locations, the dominant factor is the climate while at others the soil or repeated wildfires determine the climax.

As plant succession proceeds in an area, the natural development and replacement of vegetation types may be interrupted by catastrophic events which destroy or significantly change the existing vegetation. Following a catastrophe, plant succession continues but often at a different rate. In order to understand the changes of vegetation in the San Bernardino Mountains caused by oxidant air pollution, knowledge of how other catastrophes have influenced plant succession is necessary.

Wildfire

Fire is a major factor influencing succession in all of the vegetation zones of the San Bernardino Mountains with the exception of the desert chaparral and Pinyon-Juniper zone. The adaptations for surviving fire exhibited by a great number of the species in the chamise-chaparral and woodland-chaparral zones indicates evolution in an environment where fire was frequent.

Fire in pre-historic times was due to lightning and Indian use and misuse of fire. Opinion varies as to the degree of burning by Indians prior to the Spanish settlement of the California coast (Burcham, 1959; Aschmann, 1959). Regardless of their cause, fires must have burned freely and extensively in primitive times. During the Spanish period (1769-1822), fire was introduced as a management tool to improve forage for livestock.

The records of the extent and frequency of fires in the San Bernardino Mountains prior to 1910 are sketchy (LaFuze, 1971). From 1911 to 1971, the U.S. Forest Service has kept fire records at the Forest Supervisor's Office, San Bernardino National Forest, summarized in Figure A3. This map includes all of those fires which burned in or on the edges of the conifer zone. For simplification, fires which occurred only in the lower chaparral zones were omitted. The Cajon Pass area, for example, in the western one-third of the map, was a complex of overlapping fires whose frequent occurrence there may be related to the major rail route through the pass.

Fire has had its greatest influence on the conifer zone in the western half of the mountain region where logging activity was extensive starting in 1852 (Fig. 4). Fires prior to 1910 were frequent, occurring in 1869, 1874, 1879, 1894, 1900, and 1903 in various parts of the forest.

In the eastern half of the mountain region (Fig. 3). fires have been less frequent and in some cases appear to be caused by lightning. There are references, however, which suggest that ranchers burned the rangeland annually to improve the forage for the cattle in this eastern sector from the 1860's to the early 1900's (Vestal et al., 1904; Horton, 1960).

Fire and Plant Succession

Examinations of the influence of fire on the composition of vegetation types and plant succession in the chaparral zones indicate the capacity for sprouting following burning exhibited by many species (Horton and Kraebel, 1955; Hanes, 1971). Burned-over chaparral lands return to a chaparral cover within a few years after burning as a result of sprouting. Establishment from seeds also contributes to post-fire vegetation since the seeds of many species are stimulated to germinate by high temperatures (Stone and Juhren, 1951). As long as fire is a factor in the environment of the chaparral zones, a mosaic of scrub dominated vegetation types will be encountered.

Chaparral dominated watersheds are subject to severe erosion following burning. The annual winter floods which follow the summer and fall fires cause severe damage to urban developments at the base of the mountains, therefore great effort is being made to control these wildfires in the San Bernardino Mountains. As fire control becomes more effective and the area burned is reduced, the fire climaxes can be expected to succeed to climatic and edaphic climaxes in the chaparral zones. Horton and Kraebel (1955) suggest that elements of the woodland-chaparral zone, particularly species from the live oak chaparral and live oak woodland vegetation types, would become dominant in the absence of fire. Hanes (1971) disagrees because several plots which have not burned in the last 100 years are still dominated by chamise (Adenostoma fasciculatum). He concludes that a chamise dominated chaparral (pure chamise-chaparral, chamise-ceanothus chaparral, chamise-manzanita chaparral) would maintain itself on south-facing slopes and on the desert side of the mountains in the absence of fire. On north-facing slopes on the ocean side of the San Bernardino Mountains, scrub oak-chaparral, live oak chaparral, and live oak woodland would compose the mosaic of climax types if fire were eliminated.

In the woodland chaparral, the big-cone Douglas-fir stands are more and more confined to the steep, easily-eroded draws under the influence of repeated fires; and the canyon live oak (Quercus chrysolepis), and some shrubs (Arctostaphylos spp. and Ceanothus leucodermis) occupy the surrounding slopes. When the oaks and other species sprout after fire, some new seedlings of big-cone Douglas-fir may become established in the understory. During a long absence of fire, the firs begin to emerge from the canyon live oak canopy thereby extending the fir forest out from the refuge of the steep draws where fire seldom penetrates. The success of the new fir forest depends on whether the trees have grown large enough to survive the next fire (that is, with foliage reaching above the oak canopy and with stem bark thick enough to withstand heat). If fire occurs soon, the new fir seedlings will be destroyed and the oaks, manzanita, and chamise will sprout anew (Horton, personal communication).

Occasionally, ponderosa pine will extend down into the upper limits of the woodland chaparral on relatively gently sloping ridges with deep soil. These "stringers" of pine forest surrounded by shrubs and canyon live oak are very vulnerable to fire and suffer from severe competition for soil moisture with the chaparral species.

Fires have been frequent in the timberland chaparral zone of the San Bernardino Mountains (Fig. A3). The species in the timberland chaparral adapt to burning like the chaparral species at lower elevations, but recovery of vegetation following a fire is slower due to the shorter, cooler growing season at the higher elevations.

Fires in the coniferous forest zone were very frequent and destructive until the last 20 years (Fig. A3) when more successful fire protection has limited both frequency and spread. Large fires in this zone have often originated in adjacent chaparral areas (Fig. A3). Fire control has had a distinct influence on the structure and composition of forests in the coniferous forest zone. Periodic ground fires in this area prior to the twentieth century resulted in a low level of fuel on the forest floor. Seedlings and saplings of white fir (Abies concolor) and incense cedar (Libocedrus decurrens) were killed by these fires while pine and oak seedlings survived. A map and other descriptions in LaFuze (1971) refer to the San Bernardino "Mountain Pinery" during the 1850's when loggers were cutting the virgin forest. This suggests a very large amount of ponderosa and some sugar pines in the virgin forest.

With the reduction in ground fire that came with the establishment of the National Forests, an accumulation of ground fuel has occurred (Dodge, 1971). The once open structure of the forests has changed to one composed of flammable seedlings, saplings, and pole-sized trees reaching from the ground into the crown canopy. Under these conditions fire can have a much greater impact on the forest than in previous times. Fire in these forests today is capable of destroying existing vegetation and initiating a secondary succession in which timberland chaparral is likely to develop and may retard the succession back to the conifer types.

Not all vegetation types within the coniferous forest zone are equally susceptible to destruction by fire. The sugar pine-white fir forests which occur on south-facing slopes are typically open forests with practically no understory. Fire spreads very poorly in these forests because the areas between trees and scattered shrubs are usually bare with surfaces of eroding soil, rock slides, or rock outcroppings.

In the grassland type, fire is also less common because of the very moist meadow conditions. Fires do occasionally burn over grassland areas in the late summer and fall, but do not destroy the type.

Barren areas at high elevations are seldom exposed to fire. Following fires, the thin lodgepole and limber pine stands of the barren areas are replaced by timberland chaparral and succession back to former condition is very slow.

In the drier zones on the desert side of the San Bernardino Mountains, fire is uncommon (Fig. A3) because the wide spacing of plants in this area discourages its spread. The desert chaparral type includes many species which are capable of sprouting after a fire, but regrowth of vegetation is very slow. The species of the Pinyon-Juniper woodland zone are not adapted to withstand burning and pinyon pine (*Pinus monophylla*) in particular is nearly always destroyed. However, fires are not frequent in this zone (Fig. A3).

Man's Activities Influencing Succession in the Conifer Zone

Logging has exerted a heavy influence on the vegetation of the conifer zone of the San Bernardino Mountains since 1852 when Mormon settlers began to cut timber in the general vicinity of present-day Crestline (first Seeley Flat). The progress of early logging, including harvest of big-cone Douglas fir at lower elevations, from 1830 to 1930 (La Fuze, 1971) is presented in arbitrarily chosen intervals of 20 years (Fig. A4). During this time span, the timber harvest proceeded eastward into virgin timber until 1891 when some mills were re-established in the western areas formerly cutover.

During the first 40-50 years (beginning 1852), many of the larger trees were left standing because the water or steam-powered sawmills could not accommodate them and it is probable that the soil and younger trees were not seriously disturbed by the ox-drawn log wagons.

Timber harvest reached its peak from 1898 to 1912 with the establishment of the Brookings sawmill and the narrow gauge logging railroad near the present location of Running Springs (Fig. A4). The Brookings Company clear-cut most of the 8,000 acres of timber available to them. Trees of all sizes were cut due to the demand for boxes from the booming citrus packing industry in the valley below. The snaking of logs to rail cars by cable caused great damage to seedling trees and to the soil surface Following a severe 3,500-acre fire caused by the Brookings locomotive in 1903, the Company was prohibited from further operation on government land (La Fuze, 1971). Part of this area was later converted to timberland chaparral (Horton, 1960).

Gold mining and cattle ranching were the primary activities in the Big Bear Lake vicinity and commercial logging there did not thrive. Some steam engines at the mines had sawmill attachments and much timber was harvested for mine construction, houses, and fuel. During the early 1900's, about five sawmills near Big Bear Lake provided lumber for local construction. The placer mines and the wastes from deep mines eliminated many trees resulting in the issuance of citations by forestry officials (La Fuze, 1971).

After 1930, commercial logging in the San Bernardino Mountains was limited and sporadic. The two most most valuable timber species have always been sugar and ponderosa pine. White fir, which is difficult to season, and incense cedar, with a high percentage of dry rot, were rarely used (Parish, 1894).

Today, sanitation salvage logging is practiced whereby only "high risk" trees weakened by age or by chronic damage from oxidant air pollution are removed (Hall and Pierce, 1965). These trees are highly susceptible to attack by pine bark beetles (Dendroctonus spp.) and the practice of removing them is defended as a method of limiting the population build-up of the beetles through elimination of their food and lodging.

From 1948 to 1971, 132 contracts were executed, in many cases to remove fire damaged timber. On most stands, 10 to 15 percent of the stand is removed in each cut and the same area is recut in 5 to 10 years depending upon the accumulation of trees severely damaged by smog and bark beetle activity.

Figure A5 shows 29 areas on which more than 50,000 board feet was cut between 1948 and 1971. Barton Flats and Holcomb Valley have been cut twice during this period and one small parcel in the heavily smog-damaged area near Lake Arrowhead has been cut three times.

Salvage logging is undoubtedly a significant factor influencing succession in the conifer stand. The selective logging of ponderosa and Jeffrey pines reduces seed production of these species because the larger trees are removed. After 16 years of observation, Fowells and Schubert (1956) reported that the larger, dominant ponderosa pines produced more than 99 percent of the cones. Furthermore, even the small amount of soil surface disturbance by tractors and skidding logs provides a mineral soil seedbed favorable to the white fir and incense cedar, both of which are less important commercially and are more susceptible to fire. These circumstances coupled with constant air pollution damage and growth suppression of the more sensitive pines may lead in the ponderosa pine-white fir and sugar pine-white fir forest types to a higher density of less valuable and more fire vulnerable timber species such as white fir and incense cedar.

Another impact of logging has been an increase in the rate of fire spread. Countryman (1955) relates this increase to a change in microclimate resulting from the logging of closed canopy forests. Rate of fire spread was shown to increase up to four and one-half times in logged-over forests. If the replacement stock in the understory is white fir or incense cedar as indicated above, fire mortality greater than for ponderosa or Jeffrey pine would result.

Since 1911, 850 acres were reforested in the San Bernardino National Forest (not including the San Jacinto Mountain area). The species planted included Jeffrey, ponderosa, sugar, Coulter, and knobcone pines and the Jeffrey-Coulter hybrid. Small plots of Sierra redwood are included within the planted areas. Poor seedling survival has made it necessary to replant and interplant the same areas. Seedling survival was generally poor, but has improved slightly since 1965 because of improved planting methods and more favorable soil moisture (file reports, San Bernardino National Forest).

Fires have destroyed several of the better plantations throughout the years. For example, the Bear fire in 1970 wiped out a successful plantation near Thomas Hunting Ground.

The areas which are selected for replanting represent the best sites most favorable for tree growth. This practice results in a very "spotty" pattern of tree replacement. With generally poor survival, the total effect of replanting at the current rate is not a major factor affecting succession in the conifer forest.

In 1890-1910, when the larger virgin timber was gone from the mountains and the Arrowhead and Big Bear reservoirs were built, the recreational use and urbanization of the mountains boomed. In 1893, the San Bernardino Forest Reserve (National Forest) was created and in 1929 the San Gorgonio wilderness area was set aside. In 1929, 2 million visitors were counted entering the mountain area, more by far than entered any of the famous national parks. Today nearly 9 million visitors enter the forest annually.

The distribution of the permanent residents and recreational activity is indicated in Figure A6a and b. The shape of the four 1970 census tracts (Running Springs approximated) and data for permanent residents and dwelling units was obtained from SCRIS Report No. 3 (1971) (Fig. A6a). The projection of population and land use in the mountain communities from 1970 to 2020 prepared by Urbanomics Research Associates (1970), says "the fact that a high percentage of the lands in question are designated as National Forests suggests minimal urban and economic development in these areas in the future." However, the increasing attraction of the mountains for recreation may well result in the construction of high rise developments.

Low to high intensity use of public land represented by the wilderness area, picnic sites, improved campgrounds, and water and snow sports activity in 14 Recreational Information Management areas in 1970 is shown in Figure A6b (File report, San Bernardino National Forest). Roads alone occupied 336 acres in the Crestline-Lake Gregory areas in 1961 (Villa-Lovas, 1961).

Man's activities other than logging which alter the physical environment of the forest include all of the characteristics of urbanization:

1. Disturbance has resulted from the construction of major highways and streets in a terrace-like configuration in new forest communities. Normal drainage is disrupted and those trees not removed have their root systems exposed or buried by cut and fill. Asphalt is often placed over root systems and winter-salting of major roads causes salt damage to road side trees. Constant trimming and tree removal is done in power and telephone line corridors.

2. A vast increase in the number of recreationists using the forest can deplete forest litter and compact the soil with heavy foot traffic. Ponderosa pine is the species least likely to survive in campgrounds because of bark beetle attack on larger stressed trees and mechanical damage to seedlings (Hall and Pierce, 1965; Magill, 1970). The increase in off-trail motorcycle use, especially impromptu hill climbing on steep slopes, has produced a labyrinth of erosion scars where understory vegetation and conifer seedlings have been torn from the soil.

c 3. The disposal of treated sewage water from mountain communities presents difficult problems. At present, Lake Arrowhead's effluent is being sprinkled from settling ponds onto chaparral vegetation in Maloney Canyon northeast of the Lake where a controlled study of the effects of irrigation on natural vegetation is in progress (Fig. A6a). Big Bear Lake communities pump treated sewage water into the "dry" Baldwin

Lake because permission was denied for dumping into Arrastre Creek which drains north to the Mojave Desert communities (Fig. A6a). The Crestline-Lake Gregory area has many septic tanks and leach lines, but is being converted to a sewer system.

4. Fire control in the urbanized and heavily used forest has resulted in the accumulation of large fuels on the forest floor. If a catastrophic wildfire should break out of control in the conifer forest, these additional fuels could produce a hotter fire to kill even the larger trees (Dodge, 1971).

Influence of Abiotic Agents on Succession in the Conifer Zone

In addition to fire, the three most important abiotic agents influencing tree growth, survival, and plant succession are drought, winter drying, and breakage by accumulated snow and ice.

Extended droughts occurred in 1893, 1894, and 1917 (La Fuze, 1971) and during the late 1950's and early 1960's. Species respond differently to drought so that changes in stand composition and type distributions are to be expected. A differential response of seedlings of conifer species to drought in the ponderosa pine-white fir forest type has been demonstrated and indicates that prolonged drought would result in a shift toward Jeffrey and ponderosa pine in this type (Stone, 1957).

Winter desiccation causes injury to many trees in the coniferous forest zone as a result of an excess of transpiration over water absorption on warm sunny winter days when soil is cold or frozen. The impact of winter desiccation has not been studied in the San Bernardino Mountains. However, the extensive areas over which it occurs suggests that this damage may be significant in the development and composition of vegetation types, especially on exposed ridge crests where heavy accumulations of ice break the tops of the tree causing the crown to be flat-topped. John Muir commented on this in an 1896 visit there with Pinchot. Ponderosa pine withstands the rigors of the ridge crest better than other species.

The Effect of Tree Diseases on Succession in the Conifer Zone

The infectious tree diseases of importance in the Pinyon-Juniper and main conifer zone may be categorized as root rots, stem rots, limb and gall rusts, needle diseases and both dwarf and true mistletoes.

Root Rots

Armillaria mellea, the oak root fungus, is a very widespread inhabitant of the roots of many woody plants (Raabe, 1962). It is only occasionally detected as the cause of death of pines and firs in this area mainly because it becomes lethal only on trees weakened by some other agent. Proof of its common occurrence was presented several years ago when the root systems of blown-down Jeffrey pines on Skyline and Sugar Loaf Ridges south of Big Bear Lake were inspected. Many large roots were infected; these weakened roots probably brought about the windthrow.

Annosus root disease caused by *Fomes annosus* is found in discrete infection centers involving from a few up to 20 trees, most often ponderosa and Jeffrey pines and occasionally white fir. Small infection centers occur in upper Barton Flats, eastern Big Bear Valley, and the vicinity of Big Pine Flat north of Big Bear Lake.

The black stain root disease caused by Verticicladiella wagnerii is a very serious disease of pinyon pine. Throughout nearly 8,000 acres of the Pinyon-Juniper forest, this disease has been recognized in small centers ranging from one-fourth to one acre. It does not attack juniper but it was found on one occasion on Jeffrey pine. The area of most intense infection is east and south of Baldwin "dry" Lake.

Stem Rots

Parish (1894) described the common occurrence of pocket dry rot of incense cedar (Libocedrus decurrens) caused by Polyporous amarus. It is still common today and may seriously limit the longevity of incense cedar. A very extensive rot column is common in white fir (Abies concolor) but the exact decay organism is unknown. Polyporous schweinitzii is occasionally observed causing a root and butt rot of Jeffrey pine.

Rusts

The gall rust caused by Peridermium harknessii is occasionally found on ponderosa pine near Cedar Springs and Stockton Flat, and on lodgepole pine (Pinus contorta) at Dollar Lake. The limb rust found primarily on Jeffrey and ponderosa pine caused by Peridermium stalactiforme occasionally becomes locally epidemic; for example, in Green Canyon. It is controlled by pruning and tree removal.

Needle Diseases

The only needle disease of importance is caused by Elytroderma deformans. It is the major needle disease of ponderosa and Jeffrey pines in western North

America. Its perennial nature and its unique capacity to infect the host twigs enables it to maintain itself even under adverse environmental conditions. It reaches epidemic proportions near lakes and stream beds and in moist years. This disease is found regularly throughout the San Bernardino National Forest. Currently, intense infection centers are found northeast of Big Bear Lake and in the upper Barton Flat area.

Mistletoes

These are the most widespread and serious parasites of conifers in the San Bernardino National Forest. Species of the true mistletoe (Genus: *Phorodendron*) infect white fir (*P. bolleanum* ssp. *pauciflorum*) and incense cedar (*P. juniperinum* spp. *libocedri*). At higher altitudes, white fir is heavily infected; the tops of older trees in particular are often covered by mistletoe foliage. The trees weaken and die or are killed by bark beetles. The mistletoe in incense cedar causes negligible damage to its host.

The greatest timber loss can be attributed to the dwarf misteltoe (Genus: *Arceuthobium*) on ponderosa, Jeffrey, Coulter, and knobcone pines (*A. campylopodum*). Branch and trunk swellings and cankers and "brooming" cause severe damage to the host. Eventually badly infected trees must be removed by sanitation salvage logging. Jeffrey pine is more susceptible to the dwarf mistletoe than is ponderosa pine and areas of severe infection may be found in the upper Barton Flat and in Holcomb Valley. Coulter pines in the San Bernardino Mountains suffer heavier infection and mortality than Jeffrey pine. *A. divaricatum* is found on Pinyon pine near Horse Springs some 8 miles NE of Lake Arrowhead and elsewhere in the Pinyon-Juniper zone.

It is evident that some of the tree diseases discussed above have a definite influence on succession, either directly by killing trees outright (Black stain root rot of pinyon pine and Fomes annosus root rot of pines and fir) or indirectly by causing removal of infected trees (dwarf mistletoe and limb rust).

Direct Effects of Oxidant on Important Species, Particularly in the Conifer Zone

Identification of the cause--Conspicuous damage to needles of ponderosa pine in the conifer zone was noticed in 1953 (Asher, 1956) but similar damage was not observed in the chaparral zones on any species at that time. This new damage of unknown cause or origin was at first believed to be related to the black pine leaf scale [Nuculaspis californica (Coleman)], but a survey and subsequent map by Stevens and Hall (1956) showed no coincidence between the occurrence of heavy scale infestation and the new "needle dieback" of ponderosa pine.

The suggestion that an air pollutant might be the cause of this new disease (Asher, 1956) led to an investigation, beginning in 1957, for the Kaiser Steel Corporation to determine if flouride emission from the Kaiser plant at Fontana was responsible for the damage. Analysis of needle tissue did not indicate sufficient flouride accumulation to cause injury, but the data gathered from 1957 until about 1961 suggested that damage was related to smog (Kaiser Steel Corporation file reports, 1956-1961). The investigators noticed the same symptoms on Coulter, Jeffrey, and sugar pines in the conifer zone and similar mottle symptoms on wild grape, California sycamore, big leaf maple, and willow in the drainages.

Parallel observations described the "chlorotic decline" of ponderosa as characterized by a progressive reduction in terminal and diameter growth, loss of all but the current season's needles, reduction in number and size of the remaining needles, yellow mottling of the needles, deterioration of the fibrous root system, and eventual death of the tree (Parmeter, Bega, and Neff, 1962). Examination of roots, stems, and needles failed to disclose the presence of pathogenic organisms. An extended period of drought from 1946 to 1960 coincided with the first observations of the condition. Examination of annual terminal growth indicated that healthy trees responded to increases in precipitation, but trees in decline did not. The inception of the decline corresponded with reports of air pollution injury to grapes in the San Bernardino Valley not more than 15 air miles away (Richards, Middleton, and Hewitt, 1958).

In 1960, reciprocal bud and twig grafts were established between healthy and chlorotic decline trees growing side by side (Parmeter and Miller, 1968). Four years' observation of these twig grafts led to the conclusion that a graft transmissible agent, namely a virus, was not present and could be discounted as a possible cause of the decline disease. Fertilizer was applied once to decline trees and observations for four growth seasons indicated no improvement of tree condition (Parmeter and Miller, 1968). Mechanical injury inflicted upon root systems of healthy trees did not induce chlorotic decline symptoms nor did removal of all ages of needles over a two year observation period. However, the needles of ponderosa pine treated with 0.5 ppm ozone in plastic enclosures for 9 to 18 days under field conditions developed a chlorotic mottle, terminal dieback, and accelerated abscission similar to needle symptoms of chlorotic decline (Miller et al., 1963) and the chlorophyll content of needles treated with ozone for 18 days was generally less than that of ambient air controls.

A series of studies extending from 1957 to 1966 (Richards et al, 1968) identified ozone as the cause of the symptom syndrome referred to by Parmeter as "X-disease" and "chlorotic decline" and the name "ozone needle mottle of pine" was coined (Richards et al., 1968) to specifically name the causal agent and permit the inclusion of other pine species exhibiting similar symptoms.

Studies concentrated mainly in the Crestline-Lake Arrowhead area (Asher, 1956 Hall and Stevens, 1956) indicated the damage, which extended for 12 miles from west of Crestline to just east of Lake Arrowhead along the undulating ridge crest, was most severe at Crestline. Evidence of the oxidant or ozone injury at Running Springs, Camp Angeles and Forest Home areas was also reported (Kaiser Steel Corp., Edmunds and Richards, 1959).

In the summer of 1969, damage to the ponderosa-Jeffrey pine stands in the San Bernardino National Forest, excluding the Big Bear Lake area but including San Jacinto peak and the San Gorgonio Wilderness area, was estimated by use of special aerial photographic techniques developed by the U.S. Forest Services's Pacific Southwest Forest and Range Experiment Station. Of the 160,950 acres of ponderosa-Jeffrey type within the forest boundaries, 46,230 acres had heavy smog damage; 53,920 moderate damage; and 60,800, light or no damage. An estimated 1,298,000 individual trees were affected: 82% moderately, 15% severely and 3% completely dead (Fig. A7, Wert et al., 1970).

The extent and severity of damage to shrub and tree species in the chamise chaparral and woodland chaparral is not known. Severe damage to the big-cone Douglas-fir and slight damage to knobcone pine has been recognized in the woodland chaparral (Miller and Millecan, 1971), but damage to shrubs such as ceanothus and manzanita has been ignored or unrecognized.

Measurements of the concentration gradients of total oxidant from the basin at the city of San Bernardino up to the mountain crest on the south-facing slope have shown the highest concentrations and longest duration of concentrations greater than 0.10 ppm to be in the lower woodland chaparral zone (Miller, McCutchan, and Ryan, 1970).

Incidence of bark beetle infestation

The sometimes sudden death of declining trees prompted field studies to determine the role of bark beetles in the over-all picture and to compare some physical and physiological characteristics of healthy and diseased trees which could relate to increased susceptibility to beetle attack or greater attraction of beetles. A survey was made in 1966 to determine the severity of the decline at the time of attack and to establish for future examination neighbor trees which were also under the influence of air pollution and which would be adjacent to emerging bark beetle broods from the killed tree (Stark et al., 1968).

Trees exhibiting advanced chlorotic decline symptoms were more frequently attacked by the western pine beetle, *Dendroctonus brevicomis* LeConte, and the mountain pine beetle, *D. ponderosae* Hopkins, than those exhibiting less severe symptoms of decline. There was no apparent relationship of insect attack or chlorotic decline with crown class, total height, length of live crown or diameter.

As a test of the survey results, 100 trees in each of three disease categories --advanced, intermediate, and healthy--were examined intensively for history of insect attack. The findings substantiated the survey results: of 60 trees showing incidence of bark beetle attack, 36 were in the advanced category, 19 in the intermediate, and 5 in the healthy group. These data suggested that chronic oxidant air pollution injury predisposes sensitive ponderosa pine to bark beetle attack.

Selected physical and physiological characteristics of healthy and oxidant injured trees

Oleoresin exudation pressure, yield, flow rate and crystallization rate, sapwood and phloem moisture contents, and phloem thickness were observed (Cobb et al., 1968). Chronic oxidant injury caused a reduction in oleoresin exudation pressure and the crystallization rate of oleoresin increased with disease severity. The moisture content of both sapwood and phloem tissues showed a decrease from the healthy level in both intermediate- and advanced-diseased trees. There was also a progressive decrease in phloem thickness with increase in disease severity.

The subsequent effect of chronic photochemical atmospheric oxidant injury on xylem oleoresin composition, phloem sugars and reserve carbohydrates, and phloem pH of ponderosa pine was studied (Miller et al., 1968). Oleoresin samples from healthy and advanced-diseased trees were analyzed for differences in monoterpenes and resin acids, but no significant differences between healthy and injured classes were found, nor was there significant difference in quantities of selected resin acid compounds present in healthy and diseased trees.

Samples for phloem carbohydrates were taken from groups of healthy, intermediate-, and advanced-diseased trees. There was a reduction generally in the amounts of sugars and reserve polysaccharides, but only the decrease in reserve polysaccharides comparing intermediate- and advanced-diseased trees in the summer was statistically significant. There was no significant change in phloem pH due to the disease.

Histological and histochemical appraisal of ozone damage to needle tissue

Chloroplasts aggregated in the peripheral portions of mesophyll cells within 5 days after the start of ozone fumigation (0.45 ppm). Concurrently, the homogenous distribution of proteins and nucleic acids was disrupted. Acid phosphatase activity increased within mesophyll cells during ozone exposure. Mesophyll cell wall destruction occurred after appreciable intracellular damage. Histological and histochemical changes occurred within 5 to 7 days while macroscopic symptoms were not visible until two to three weeks after fumigation (Evans and Miller, 1972a).

Two pine species most sensitive to ozone (ponderosa and Jeffrey) exhibited a larger number of stomata per cross-sectional area of mesophyll cells while the number of mesophyll cells per stomata was lower. The number of hypodermal layers and thickness of epidermal and hypodermal layers was negatively correlated with ozone sensitivity. In the more ozone tolerant pine species (Coulter and sugar), initial injury was more closely associated with substomatal mesophyll cells. Oxone injury occupied a greater length of the entire needle of the sensitive species as evidenced by the proximity of symptoms to the needle base (Evans and Miller, 1972b). These results suggest that needles of ozone sensitive species may be more "ventilated" than those of tolerant species.

Changes in apparent photosynthesis

Three-year-old ponderosa pines fumigated in controlled environment chambers with ozone at 0.15, 0.30, or 0.45 ppm had apparent photosynthesis rates reduced by 10, 70, and 85 percent, respectively, after 30 days exposure. A fumigation with 0.30 ppm ozone for 33 days reduced the polysaccharides content of both current and one-year-old needles by 40 percent. Soluble sugar content of current year, ozone-injured needles increased 16 percent and that of the one-year-old needles decreased slightly. Higher content of ascorbic acid in one year old needles did not protect the tissue from ozone injury (Miller et al., 1969).

Apparent photosynthesis rate of whole plants after ozone injury was determined in terms of $C^{14}O_2$ uptake which made it possible to compare the apparent photosynthetic activity of current-year needles with one year old needles. One group of seedlings demonstrated that one-year-old foliage was suppressed (77 percent of control), but the current-year foliage was not (113 percent of control) even though each age of needle had lost about 25 percent of its chlorophyll (Miller, 1965).

Ozone effects on specific photosynthetic reactions

Both light requiring and dark reaction sequences of photosynthesis were investigated. The Hill reaction rates of chloroplasts isolated from healthy and ozone-injured needles were compared at several light intensities. Chloroplasts from ozone-injured needles were less capable of Hill reaction activity at all light intensities in spite of equal chlorophyll concentration. Repeated comparisons of the chlorophyll a/b ratio of extractions from O_3 injured and healthy plants did not indicate any significant change (Miller, 1965) suggesting that qualitative or quantitative chlorophyll changes are not the primary cause of Hill reaction or apparent photosynthesis depression.

The pattern of labeling by $C^{14}O_2$ in the 80 percent ethanol soluble photosynthate of healthy and ozone-injured needles was compared after $C^{14}O_2$ fixation for various lengths of time. No qualitative differences in the pattern of labeling in the photosynthate were observed following separation by two dimensional paper chromatography (Miller, 1965).

Relative ozone sensitivity of the important conifer species

Extreme variability of response has been encountered among individuals of a single species and between fumigations at different times (spring, summer, fall). Much more replication within experiments and repetition of fumigations was required than initially anticipated. The goal of fumigation work is to provide a quantitative, statistically treated estimate of the relative sensitivity of each species compared with ponderosa pine which is included in every experiment. These data are now being analyzed, but an approximation of the relative ozone sensitivity of the various species is presented in Table AII (Miller, unpublished).

Effect of oxidant (ozone) on the growth of ponderosa pine

Oxidant concentrations with average daily peaks of 0.20 ppm occurred almost every day from May through September during 1968-1970 at Rim Forest (5,680 feet) in the San Bernardino National Forest (Miller, 1971). Maximum daily concentrations as high as 0.58 ppm have been recorded repeatedly. In August 1968, groups of sapling ponderosa pines were enclosed in greenhouses. One house received activated carbon filtered air, the other unfiltered ambient air. A control group, not enclosed in a house, was observed simultaneously.

After filtered air treatment for only one year, the symptoms of needle injury virtually disappeared. Even those trees in an advanced stage of injury were able to recover in the filtered air environment. These data illustrate the amount of growth suppression due to photochemical oxidant damage which would not otherwise be visible (Miller, unpublished). In 1971, those trees in filtered air which began with only one damaged needle whorl now have four healthy whorls and the needle length of each new whorl is longer than the last. Trees receiving the two unfiltered air (ambient smog) treatments have declined in vigor and most retain only one needle whorl.

In the above experiment ponderosa pine served as an accurate bioindicator of both improved air quality and of ambient smog after only one year by virtue of changes in needle symptoms, growth, and retention. This remarkable capability of pines to serve as an information storage system was also exploited in the San Bernardino Mountains by Dr. Harold C. Fritts of the Laboratory of Tree Ring Research, University of Arizona. Figure A8 (Fritts, In Press) shows measurements of ring width variation as a function of the date of the annual rings. "The abrupt decline in width at the beginning of the 1950's and 1960's is apparent in both plots (Fritts, personal communication)." Both of the oxidant-damaged Jeffrey pines examined were cut in a sanitation salvage logging operation in 1971 in the San Bernardino Mountains. A complete statistical treatment of these data would separate the anticipated variation due to tree age and annual precipitation from variation in ring width due to air pollution. This could provide precise dating of the inception of damage and possibly reconstruct the responses of the important species in the conifer zone.

Possible Changes in Community Composition Induced by Oxidant Air Pollution

The complex of variables which interact to influence the individual plant and subsequently shape the plant community are illustrated in Figure A9, modified from Billings (1952). It is apparent that both a primary and secondary influence is exerted by oxidant air pollution in this system. The task of identifying and quantifying these influences must be performed, if only provisionally, so that hypotheses for important change can be developed and tested.

The effect of oxidant air pollution will not be the same in all vegetation zones in the San Bernardino Mountains. Measurement of oxidant concentration gradients on the south-facing slopes of the mountains above San Bernardino (Miller et al., 1970; Edinger et al., 1971) indicated that the chamise-ceanothus, chamise-manzanita and lower portion of the woodland chaparral zones receive the longest daily exposure to adverse oxidant concentration and often the highest daily maximum. However, the greatest visible damage is in the conifer zone.

The timing of severe oxidant exposure both on a daily and seasonal basis is an important factor determining damage. In the chaparral zones, the daily oxidant peak occurs during periods of lowest relative humidity, whereas, in the conifer zone, the peak oxidant occurs later in the day when relative humidity is increasing (Miller et al., 1970). What influence does humidity have on stomatal behavior and uptake of pollutant in each vegetation zone?

The Pinyon-Juniper forest and the desert chaparral are more remote and not as heavily influenced by the marine air mass bearing the oxidant air pollution. However, the Pinyon-Juniper zone and the chaparral zones cannot be excluded from consideration because of the wildlife of the conifer zone which freely use the other zones for feed or cover.

The riverine vegetation, which includes such species as California sycamore, California bay and Fremont cottonwood, deserves great attention because it is an area rich in wildlife and it often occupies the mid-to-lower elevation southern slopes which receive long oxidant exposure.

Even the lodgepole pine (*P. contorta*) and limber pine (*P. flexilis*) above 8,000 feet cannot be considered exempt from oxidant injury, especially those on the south-facing slopes of San Gorgonio Peak where the thermal updraft carries polluted air upward.

At this time, no surveys have been made to identify oxidant damage in the Pinyon-Juniper, riverine, or alpine zones.

The possible successional trends in the conifer zone have been examined in relation to site, species composition, ponderosa decline rate, mortality and silvicultural literature (Miller, 1971). The species composition and age structure in a heavily damaged 575 acre mixed conifer stand (Table AIII) show that ponderosa pine is by far the most numerous species in size classes larger than 12 inches dbh (diameter-breast-height). White fir had the greatest number of survivors in three size classes from seedlings up to poles 11.9 inches dbh; followed by ponderosa pine, incense cedars, and sugar pine. From 1969 to 1971, the mortality of ponderosa pine was 8.1 percent in a subsample of 160 trees. In this group, the number of trees exhibiting no visible injury declined from 27 in 1969 to 11 in 1971.

The 575-acre study area was a relatively smooth, undulating ridge crest overlooking the polluted air basin to the south and with an abrupt transition to a north-facing slope dissected by several small intermittent drainages. Ponderosa pine was most severely damaged by oxidant on the ridge crest where it was greatest in number, perhaps demonstrating its suitability for this more severe site. A deterioration at the forest border is suggested, emphasizing the importance of site as a factor determining succession in the conifer zone.

Hypothesis for Succession in the Conifer Zone

Earlier in this section, it was stated that ponderosa and Jeffrey pines are less affected by drought and fire than white fir or incense cedar. Sugar pine, a very desirable species because of apparent oxidant tolerance, is generally present in such low numbers that it has little potential for natural replacement of other conifers. Bark beetles, root diseases, dwarf mistletoe, sanitation salvage logging and urbanization are factors interacting with oxidant air pollution to deplete the numbers and depress the growth and regenerative capacity of ponderosa and Jeffrey pine. The growth of white fir and incense cedar is visibly retarded by oxidant damage and it is probable that other valuable shrubs and herbs are being eliminated completely from the community (Harvard and

Treshow, 1971). Thus, oxidant damage is a potent new selection pressure in the conifer forest.

Another problem of increasing importance is the large accumulation of heavy fuels (Dodge, 1971, Dell and Wilson, 1971) in the conifer zone created as a result of the smog-insect killed trees and of successful fire control policy. The more abundant white fir and incense cedar regeneration in the understory is less fire tolerant than are the pines. Catastrophic fires can penetrate the conifer forest (Bear Fire - 1970) during periods of high winds. The accumulation of heavy fuel causes a hotter fire which would destroy most of the seedlings and more of the larger trees. Also, the forest canopy is being opened up through removal of trees by construction, selective logging and mortality due to insects and smog, thus increasing rate of fire spread (Countryman, 1955). Historical records show that bad fire years occur about every 8 years (Show and Kotok, 1924). Fire causes the site to become more xeric and changes the nutrient and water status of the soil. Oxidant air pollution--the new selective force--retards the regeneration of all vegetation, both pre- and post-fire. The development of low value timberland chaparral which occurred after early logging and fires (Horton, 1960) may be repeated in additional acreages hard-hit by oxidant air pollution and by fire, thus offering very poor prospects for the future of the conifer forest. The most important element is time. The multiple effects of air pollution must be understood so that remedial action can be defined and enacted to save not only the valuable southern California conifer forests but also those of the western Sierra Nevada.

Recommendations for Future Study

1. Reconstruct the history of oxidant air pollution impact on the several important conifer species and California black oak at selected sites in the San Bernardino Mountains by the methods of dendrochronology. Growth ring width variations when standardized for tree age and precipitation records can show the relative effects of air pollution on different species, aided by X-ray techniques for measuring wood density. This would be a powerful tool for predicting future trends. An unpolluted control area would be included.

2. Carefully define successional trends in the conifer zone by a) establishing permanent observation plots to describe rate of deterioration and mortality of both trees and understory vegetation and to observe the natural replacement of these smog-killed species; and b) determining the ecological potential of the major species through controlled environment studies and ordination along gradients of important environmental factors such as elevation, soil moisture and distance from pollution.

3. Prepare better vegetation type maps with the aid of aerial photography.

4. Investigate the effects of oxidant air pollution on the physiological potential of the important species with emphasis on the reproductive stages of the life cycle: flowering, pollen germination, fertilization, maturation of seeds and fruit.

5. Determine if interactions between oxidant air pollution and the major established plant pathogens (e.g., dwarf mistletoes and root rots) alters pathogenesis or epidemiology (spread).

6. Define interactions between forest microclimate and oxidant air pollution which alters rate of pollutant uptake or tree sensitivity (e.g. thinning).

7. Identify the direct and indirect effects of oxidant air pollution on soil microorganisms (detoxification and nutrient cycling).

8. Sample and evaluate the beneficial or non-beneficial roles of root surface microflora (mycorrhizae) and the effect of oxidant air pollution on these organisms.

9. Estimate energy flow into a selected type in the conifer zone with and without oxidant exposure.

10. Investigate the effects of combinations of pollutants on ponderosa pine based upon preliminary ambient air monitoring for selected pollutants, e.g., total oxidant, ozone, PAN, SO_2, NO_x.

Recommendations assembled from suggestions of:

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Table AI. Vegetation zones, vegetation types, and major species in the San Bernardino Mountains.

Vegetation zone*	Horton's vegetation type*	Minnich's vegetation type**	Map symbol	Major species
Chamise-Chaparral	Pure chamise-chaparral	none		Adenostoma fasciculatum
	Chamise-ceanothus chaparral	Soft chaparral	C_S	Adenostoma fasciculatum. Ceanothus crassifolius, C. leucodermis, Quercus dumosa, Photinia arbutifolia, Rhus ovata
	Chamise-manzanita chaparral	Hard chaparral	C_H	Adenostoma fasciculatum, Arctostaphylos glauca. A. glandulosa. Ceanothus crassifolius. C. leucodermis
	Scrub oak chaparral	Oak chaparral	C_{SO}	Quercus dumosa, Q. wislizenii, Cercocarpa betuloides, Ceanothus leucodermis, Garrya veatchii, Arctostaphylos glandulosa
	Coastal sagebrush	Coastal sage scrub	CS	Artemisia californica, Salvia apiana, Eriogonum fasciculatum, Encelia farinosa, Salvia mellifera, Diplacus longiflorus
Woodland-Chaparral	Live oak chaparral	Emergent oak woodland	C_{WD}	Quercus wislizenii, Q. chrysolepis. plus hard chaparral species
	Live oak woodland	Interior oak woodland	$C_{WD}{}^1$	Quercus wislizenii. Q. chrysolepis, Pseudotsuga macrocarpa, Cercocarpus ledifolius
	Big-cone Douglas fir forest	Big-cone Douglas fir forest	CF_{BS}	Pseudotsuga macrocarpa, Quercus chrysolepis

Table AI. (cont.)

Vegetation zone*	Horton's vegetation type*	Minnich's vegetation type**	Map symbol	Major species
Woodland-Chaparral	Knobcone pine forest	Knobcone pine forest	CE_{KB}	*Pinus attenuata*, *Adenostoma fasciculatum*, *Arctostaphylos glandulosa*, *Ceanothus leucodermis*, *Pickeringia montana*
	none (see pine forest)	Coulter pine forest	CE_{CP}	*Pinus coulteri*, *Quercus wislizenii*, *Q. chrysolepis*, plus hard chaparral species
Desert Chaparral	Desert chaparral	Desert chaparral	C_D	*Cercocarpus ledifolius*, *Quercus wislizenii*, *Q. dumosa*, *Q. chrysolepis*, *Ceanothus greggii*, *C. crassifolius*, *Fremontia californicus*, *Garrya veatchii*
Pinyon-Juniper Woodland	Pinyon-Juniper woodland	Western Juniper-mountain mahogany woodland	PJ_D	*Juniperus occidentalis*, *Cercocarpus ledifolius*, *Artemisia tridentata*, *Chrysothamnus nauseosus*
		Pinyon pine woodland	PJ	*Pinus monophylla*, *P. quadrifolia*, *Juniperus californica*, *J. occidentalis*, *Cercocarpus ledifolius*, *Artemisia tridentata*, *Chrysothamnus nauseosus*
		Pinyon-Juniper woodland	PJ_O	*Pinus monophylla*, *P. quadrifolia*, *Juniperus californica*, *J. occidentalis*, *Cercocarpus ledifolius*, *Artemisia tridentata*, *Chrysothamnus nauseosus*, *Arctostaphylos glauca*, *Quercus dumosa*

Table AI. (cont.)

Vegetation zone*	Horton's vegetation type*	Minnich's vegetation type**	Map symbol	Major species
Pinyon-Juniper Woodland	Great Basin sagebrush	Great Basin sagebrush	GB	*Artemisia tridentata*, *Artemisia arbuscula nova*, *Chrysothamnus nauseosus*, *Colegyne ramossissima*, *Eriogonum* spp., *Salvia* spp.
	none	Joshua Tree woodland	JS	*Yucca occidentalis*, *Yucca brevifolia*, *Chrysothamnus nauseosus*
	none	Juniper-Joshua Tree woodland	JJ	*Juniperus occidentalis*, *Yucca brevifolia*, *Artemisia tridentata*, *Chrysothamnus nauseous*
Timberland Chaparral	Timberland chaparral	Timberland chaparral	CT	*Arctostaphylos patula*, *Ceanothus cordulatus*, *Castanopsis sempervirens*
Coniferous Forest	Pine forest	none (see Coulter pine forest, dry forest)		*Pinus ponderosa*, *Pinus jeffreyi*, *Pinus coulteri*, *Quercus kelloggii*
	Ponderosa pine-white fir forest	Mixed yellow pine-white fir forest	PF_M	*Pinus ponderosa*, *Pinus jeffreyi*, *Abies concolor*, *Pinus lambertiana*, *Libocedrus decurrens*, *Quercus kelloggii*
	Sugar pine-white fir forest	none (see pure yellow pine-white fir forest)		*Pinus lambertiana*, *P. jeffreyi*, *Abies concolor*, *Quercus chrysolepis*, *plus* timberland chaparral species
	Grassland	Grassland or meadow	G	*Bromus* spp., *Carex* spp., *Juncus* spp.

Table AI. (cont.)

Vegetation zone*	Horton's vegetation type*	Minnich's vegetation type**	Map symbol	Major species
Coniferous Forest	Black oak woodland	none (see dry forest)		*Quercus kelloggii*, *Quercus chrysolepis*, *Pinus ponderosa*, *Pseudotsuga macrocarpa*, *Ceanothus integerrimus*
	Alpine forest	Subalpine forest	LP	*Pinus contorta*, *P. flexilus*, plus timberland chaparral species.
	Barren areas	Krummholz	LP_K	*Pinus contorta*, *Pinus flexilus*, plus stunted timberland chaparral species.
		Barren	B	none
	none	Marginal conifer forest	TF	A mixture between pure yellow pine-white fir forest and timberland chaparral species
	none (see Pine forest, ponderosa pine-white fir forest)	Pure yellow pine-white fir forest	PF	*Pinus ponderosa*, *P. jeffreyi*, *P. lambertiana*, *Libocedrus decurrens*, *Abies concolor*
	none (see Pine forest, black oak woodland)	Dry forest	DF	*Pinus coulteri*, *Quercus kelloggii*
All Zones	none	Riverine vegetation	R	*Platanus racemosa* (below 4,000 feet) *Populus trichocarpa* (below 4,000 feet), *Alnus rhamnifolia* (4,000-7,000 feet), *Salix* spp. (above 7,000 feet), *Populus tremuloides* (Fish Creek)

Table AI. (cont.).

Vegetation zone*	Horton's vegetation type*	Minnich's vegetation type**	Map symbol	Major species
All Zones	none	Subclimax vegetation	S	Varies with site
Outside of Above Zone	none	Open desert vegetation	D	

* Horton (1960)

** Minnich (1969)

Table AII. Approximate ozone sensitivity of important western conifers.[*]

	Conifer Zone		Woodland Chaparral Zone
	San Bernardino National Forest	Sierra Nevada**	San Bernardino National Forest
Sensitive	Ponderosa Pine Jeffrey Pine White Fir	Western White Pine	Big-cone Douglas fir Monterey x Knobcone Pine Cross
Moderately sensitive	Coulter Pine Incense Cedar Rocky Mountain Ponderosa Pine	Red Fir	Knobcone Pine
Tolerant	Sugar Pine	Giant Sequoia	

---

[*] Miller, unpublished data.

** Species not native to the San Bernardino National Forest.

Table AIII. The relative numbers per acre of four conifer species in five size classes on a 575-acre study area severely influenced by oxidant air pollution.*

Size Class	Ponderosa Pine	Incense Cedar	White Fir	Sugar Pine
Seedlings up to 3.0 ft. tall	1057	2381	1043	302
Saplings more than 3.1 ft. tall & less than 3.9 inches dbh	33	33	57	10
Poles 4.0 to 11.9 inches dbh	21	12	38	3
Standard 12.0 to 23.9 inches dbh	18	9	8	3
Veteran 24.0 inches dbh and larger	12	5	4	2
Totals:	1141	2440	1150	320
% of Grand Total:	23	48	23	6

---

* Miller, 1971.

LIST OF FIGURES

Figure A1 Vegetative Zones. Horton, 1960.

Figure A2 Vegetative Types. (Minnich et al. 1969). Attached at end of report

Figure A3 Wildfires. 1911-1970.

Figure A4 Logging. 1831-1930.

Figure A5 Sanitation-Salvage Logging. 1950-1971.

Figure A6 Distribution of Permanent Population and Recreational Use. 1970.

Figure A6b Traffic Patterns in Fourteen Recreation Information Management Districts. 1970.

Figure A7 Smog Impact Area.

Figure A8 Decrease in Ring Width Growth Due to Air Pollution. (Fritts, *In Press*).

Figure A9 Suggested Interactions of Oxidant in the Forest Environment.

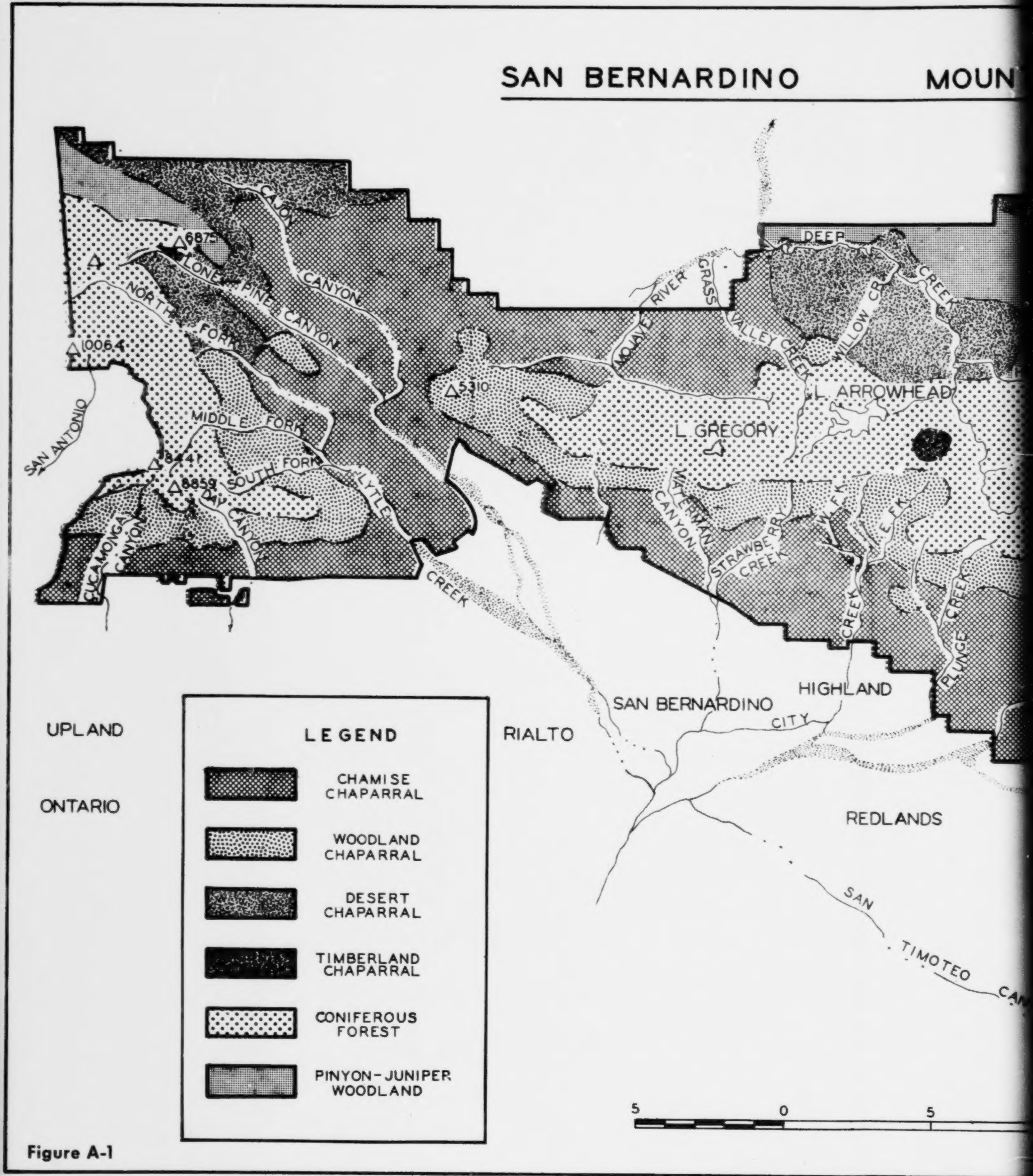
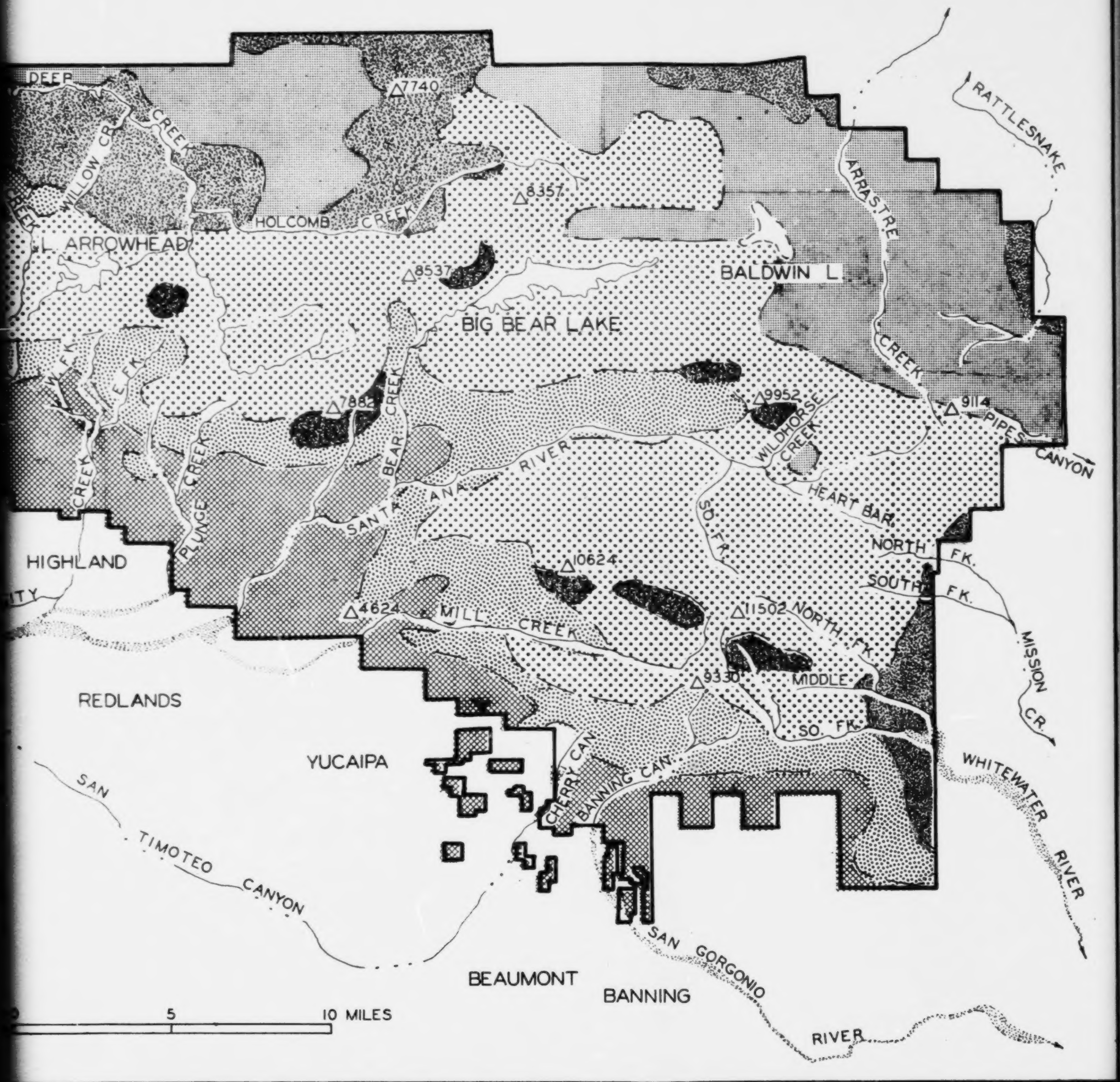

SAN BERNARDINO MOUN
LEGEND
CHAMISE CHAPARRAL
WOODLAND CHAPARRAL
DESERT CHAPARRAL
TIMBERLAND CHAPARRAL
CONIFEROUS FOREST
PINYON-JUNIPER WOODLAND
5
0
5
6875
10064
8441
8859
5310
CAJON
CANYON
LONE PINE CANYON
NORTH FORK
MIDDLE FORK
SOUTH FORK
LYTLE
CREEK
DAY CANYON
CUCAMONGA CANYON
SAN ANTONIO
MOJAVE RIVER
GRASS VALLEY CREEK
DEEP CREEK
WILLOW CR
L. ARROWHEAD
L. GREGORY
WATERMAN CANYON
STRAWBERRY CREEK
W. FK.
E. FK.
CREEK
PLUNGE CREEK
CITY
UPLAND
ONTARIO
RIALTO
SAN BERNARDINO
HIGHLAND
REDLANDS
SAN TIMOTEO CAN

Figure A-1

A. 45

O MOUNTAIN AREA


DEER
CREEK
WILLOW CR.
HOLCOMB CREEK
L. ARROWHEAD
7740
8357
8537
BALDWIN L.
BIG BEAR LAKE
RATTLESNAKE
ARRASTRE CREEK
9114
PIPES CANYON
9952
WILDHORSE CREEK
7882
BEAR CREEK
CREEK
PLUNGE CREEK
SANTA ANA RIVER
SO. FK.
HEART BAR
NORTH FK.
SOUTH FK.
MISSION CR.
HIGHLAND
CITY
10624
4624
MILL CREEK
11502
NORTH FK.
9330
MIDDLE
SO. FK.
REDLANDS
YUCAIPA
CHERRY CAN.
BANNING CAN.
WHITEWATER RIVER
SAN TIMOTEO CANYON
SAN GORGONIO RIVER
BEAUMONT
BANNING
0
5
10 MILES

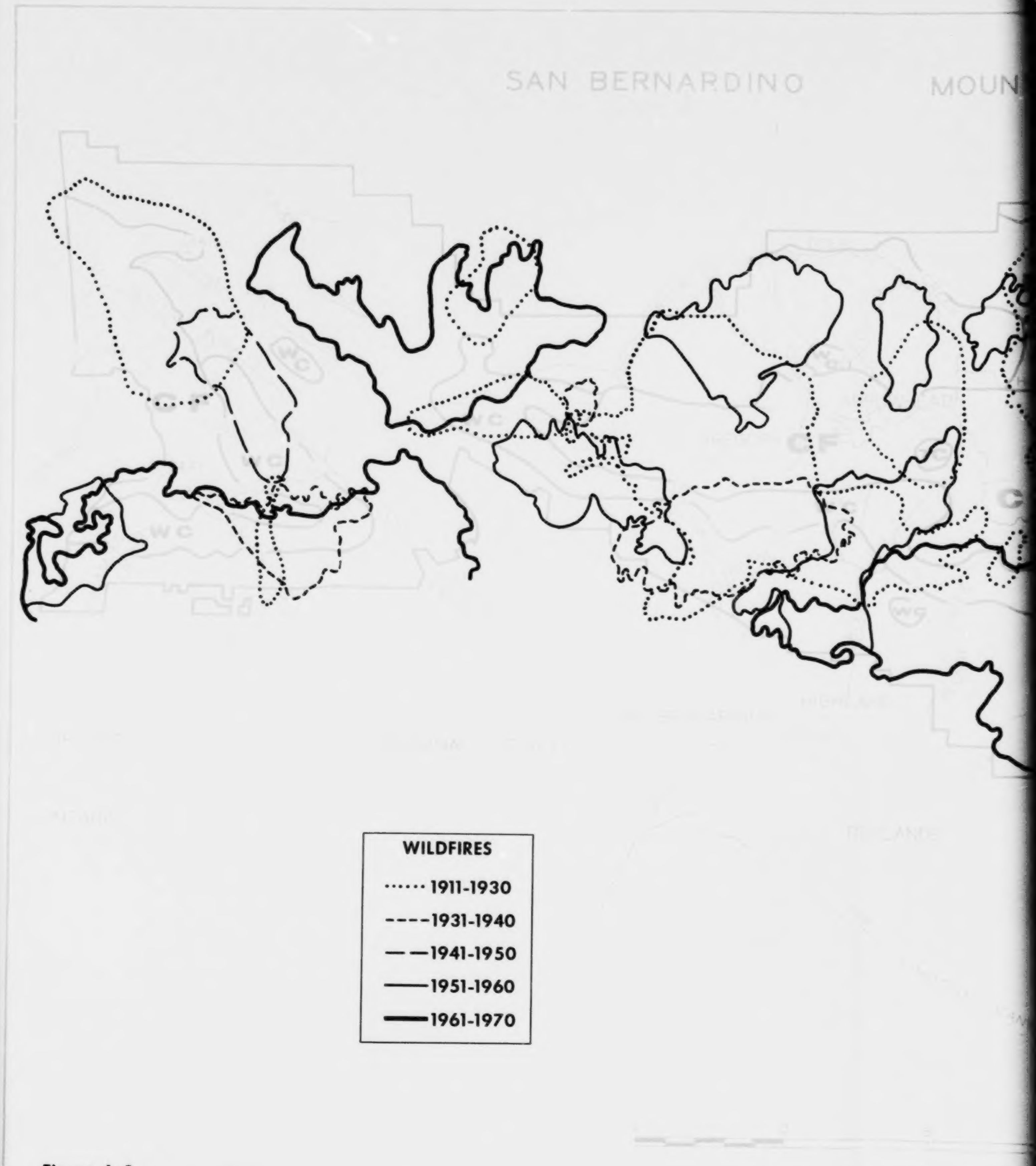
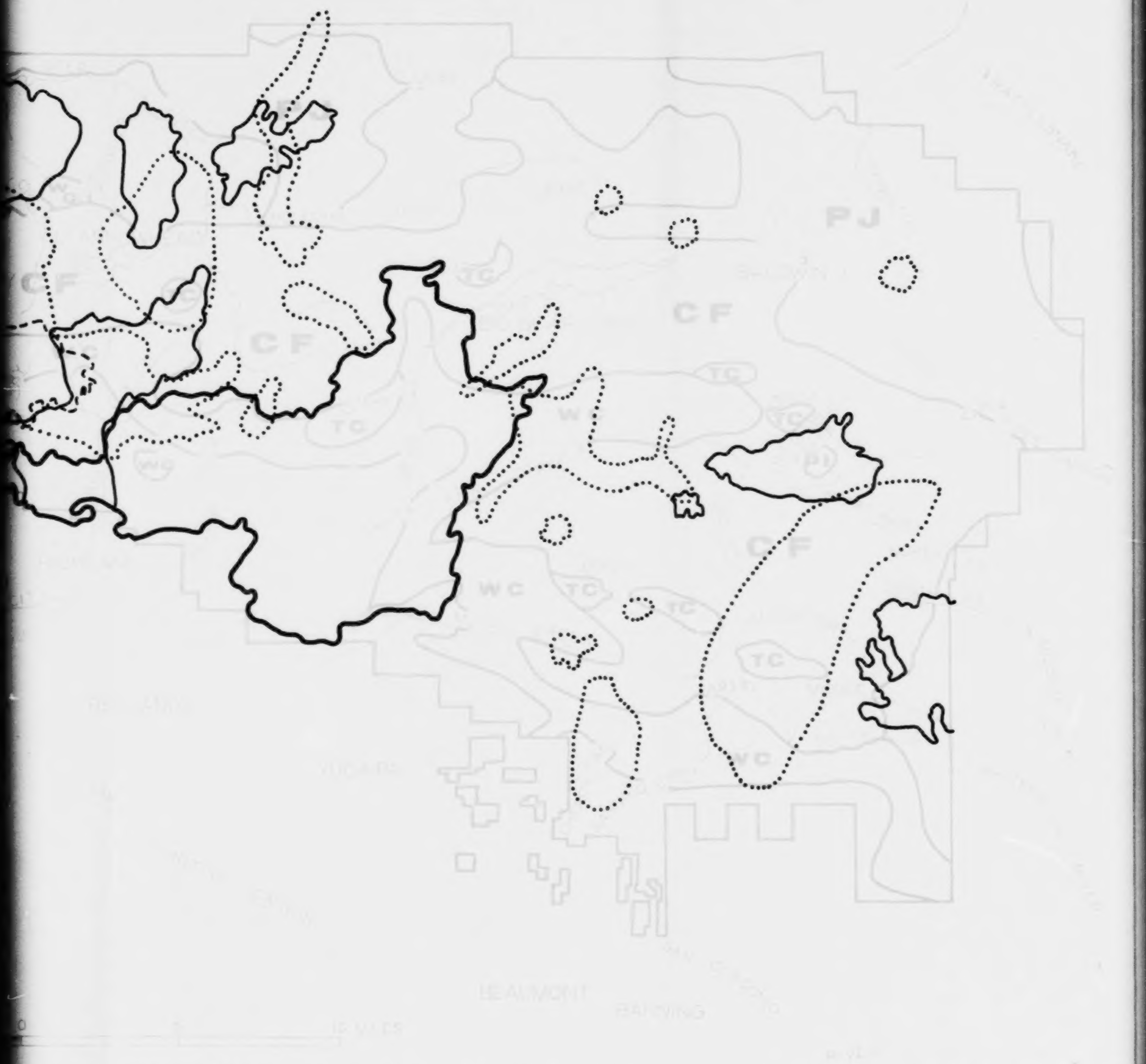

SAN BERNARDINO
MOUN
WC
CF
HIGHLAND
WILDFIRES
1911-1930
1931-1940
1941-1950
1951-1960
1961-1970
Horton 1960 VEGETATIVE ZONES

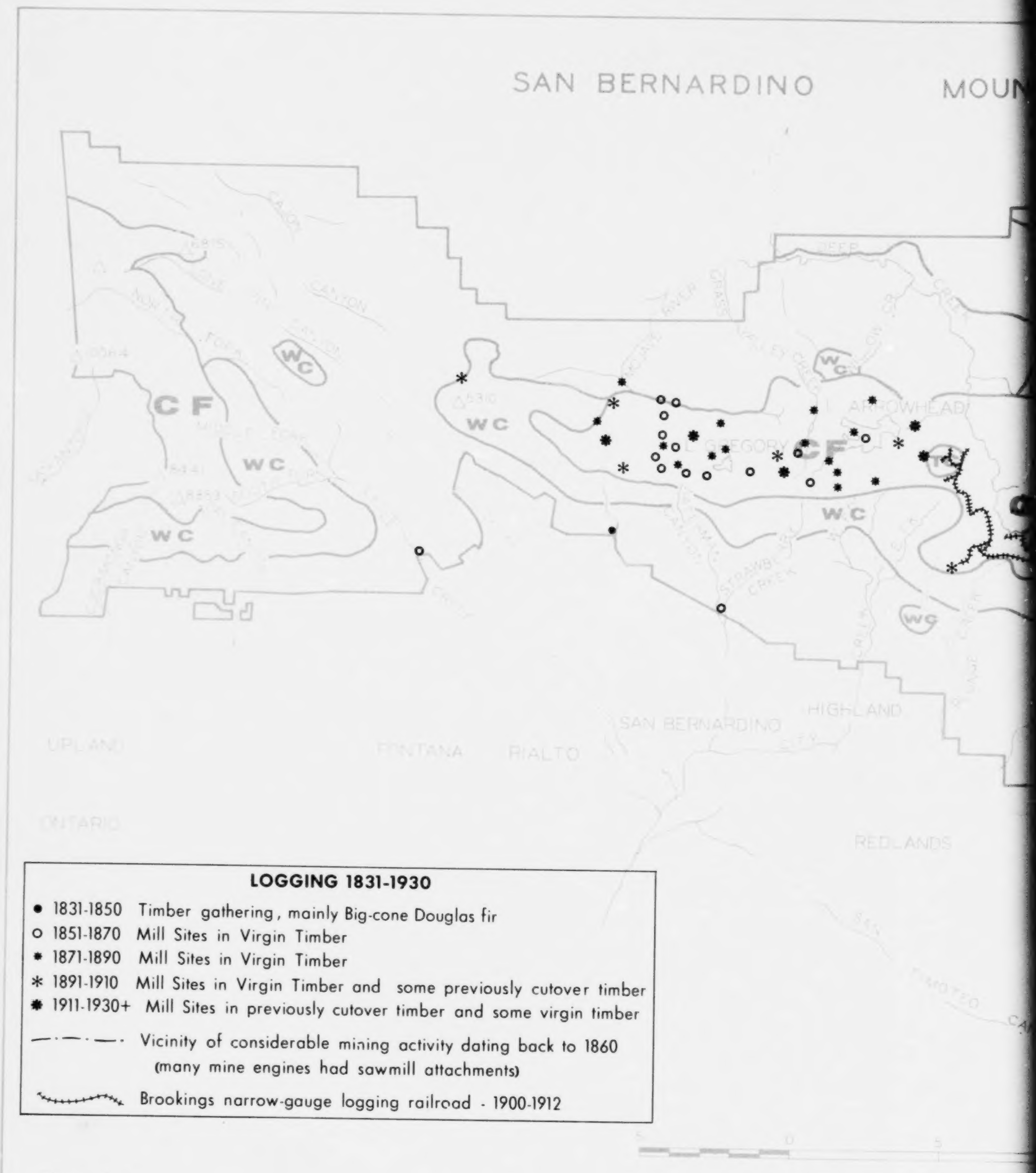
Figure A-3

A-46

O MOUNTAIN AREA


CF
CF
CF
CF
PJ
PJ
WC
WC
WC
WC
WC
TC
TC
TC
TC
TC
TC
TC
BEAUMONT
BANNING
0
5
10 MILES

orton 1960 VEGETATIVE ZONES: CF - Conifer Forest PJ - Pinyon-Juniper WC - Woodland Chaparral TC - Timberland Chaparral


SAN BERNARDINO
MOUN
CF
WC
WC
WC
WC
WC
WC
CF
WC
WC
CAJON
CANYON
NORTH FORK
DEEP CREEK
ARROWHEAD
GREGORY
STRAWBERRY CREEK
SAN BERNARDINO
HIGHLAND
UPLAND
FONTANA
RIALTO
ONTARIO
REDLANDS
5
0
5

LOGGING 1831-1930

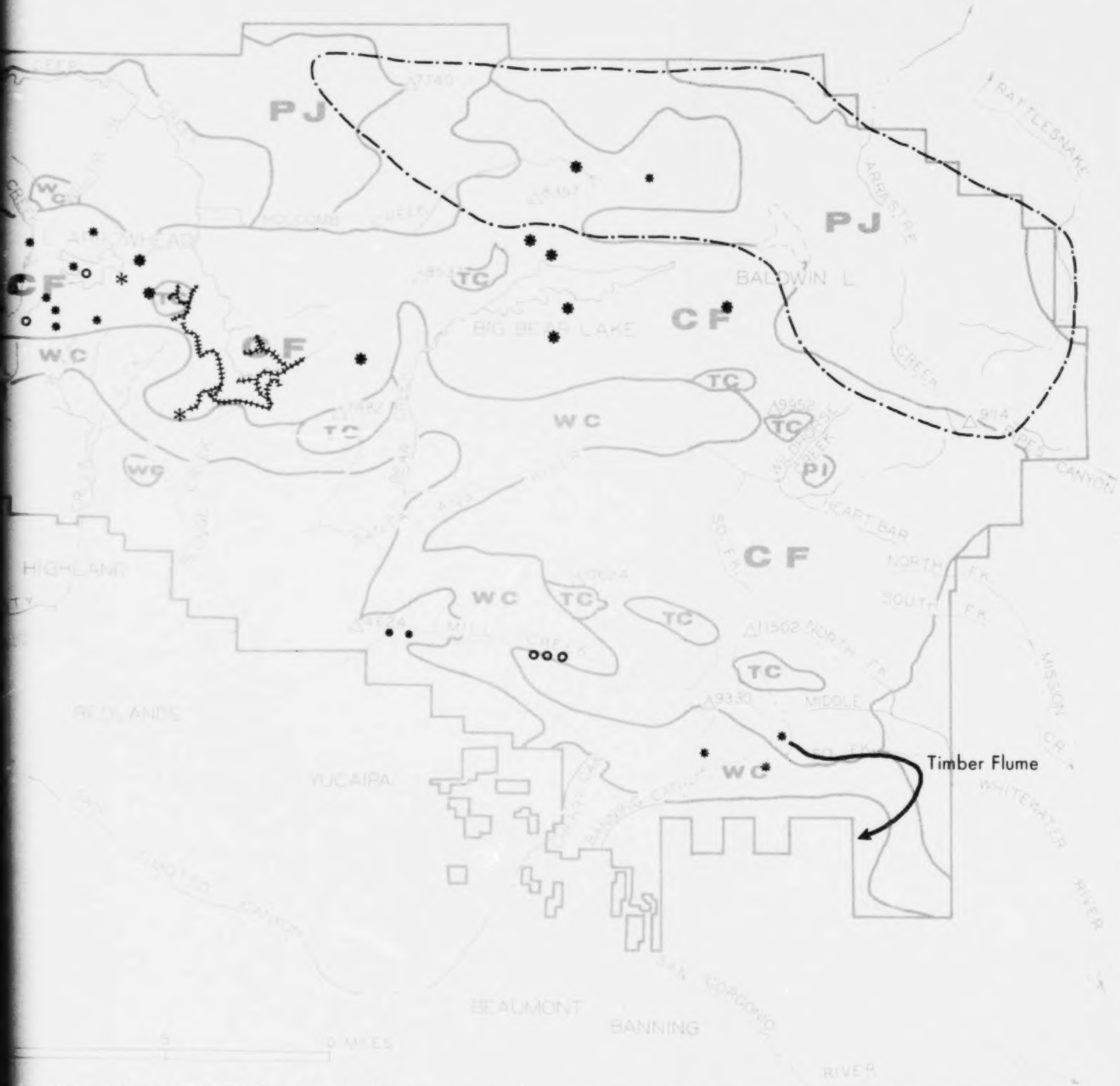
- ● 1831-1850 Timber gathering, mainly Big-cone Douglas fir
- ○ 1851-1870 Mill Sites in Virgin Timber
- * 1871-1890 Mill Sites in Virgin Timber
- ✳ 1891-1910 Mill Sites in Virgin Timber and some previously cutover timber
- ✸ 1911-1930+ Mill Sites in previously cutover timber and some virgin timber
- —·—·— Vicinity of considerable mining activity dating back to 1860 (many mine engines had sawmill attachments)
- ++++++ Brookings narrow-gauge logging railroad - 1900-1912

Figure A-4

Horton 1960 VEGETATIVE ZONES

A-47

O MOUNTAIN AREA


PJ
PJ
CF
CF
CF
CF
WC
WC
WC
WC
WC
WC
TC
TC
TC
TC
TC
TC
TC
PJ
BIG BEAR LAKE
BALDWIN L
HOLCOMB CREEK
ARRASTRE CREEK
RATTLESNAKE
PIPES CANYON
HEART BAR
NORTH FK.
SOUTH FK.
MIDDLE
MILL CREEK
BANNING CANYON
SAN GORGONIO RIVER
WHITEWATER RIVER
MISSION CR.
HIGHLAND
REDLANDS
YUCAIPA
BEAUMONT
BANNING
7740
8457
9952
9114
11502
9330
4624
Timber Flume
5
10 MILES

ion 1960 VEGETATIVE ZONES: CF - Conifer Forest PJ - Pinyon-Juniper WC - Woodland Chaparral TC - Timberland Chaparral

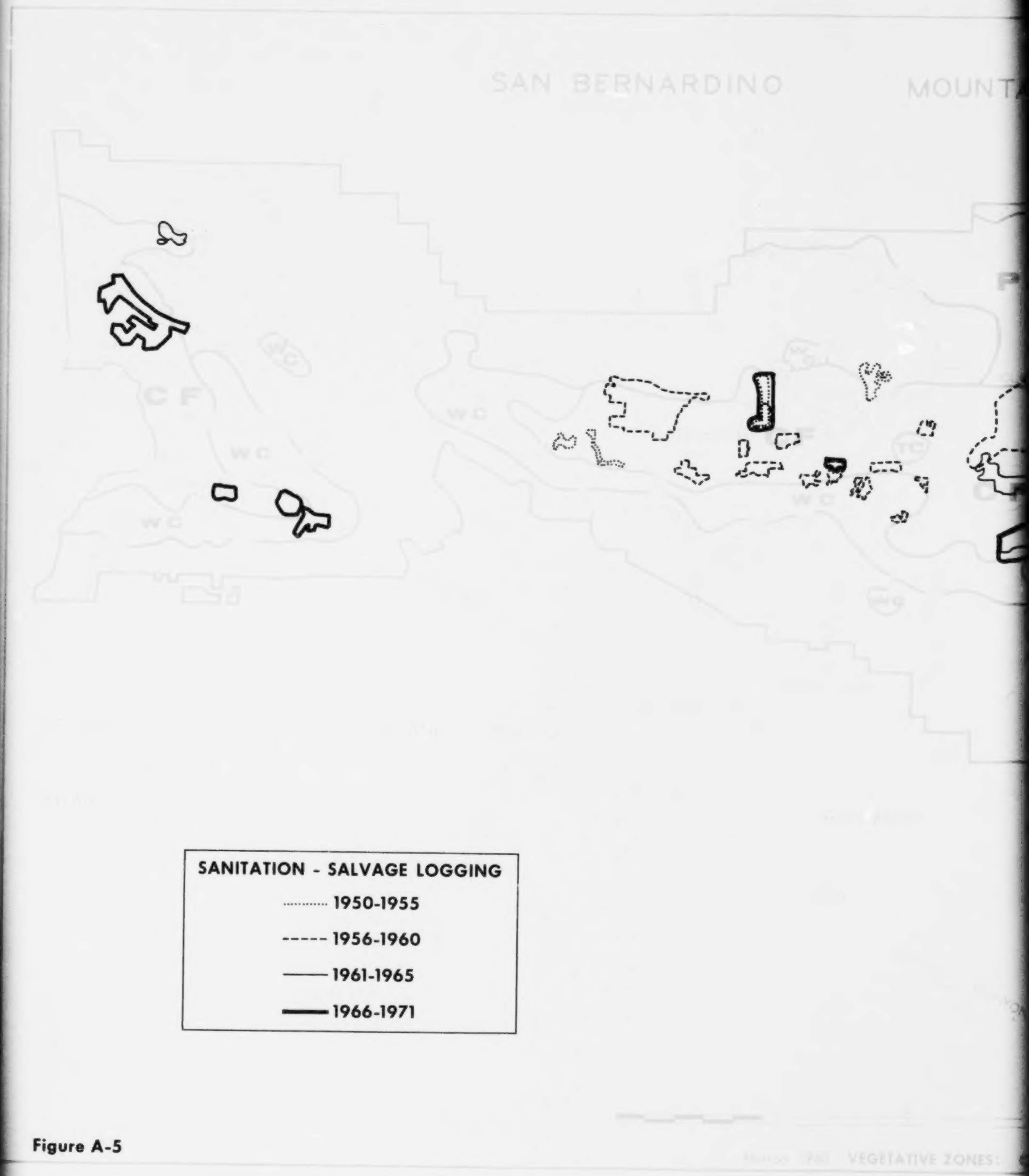
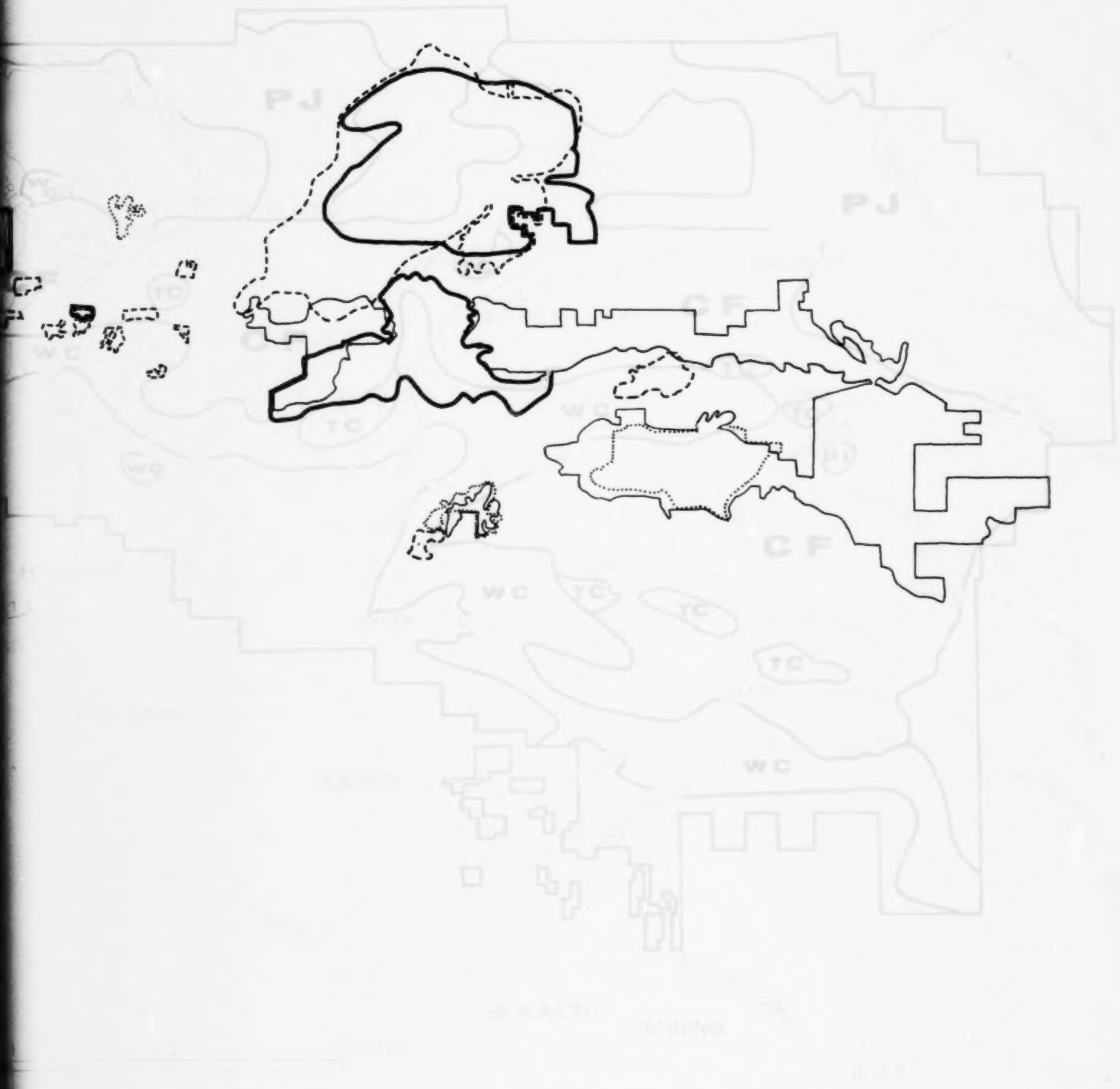

SAN BERNARDINO
MOUNTA
CF
WC
WC
WC
WC
CF
WC
WC
TC
WC
SANITATION - SALVAGE LOGGING
1950-1955
1956-1960
1961-1965
1966-1971
VEGETATIVE ZONES:

Figure A-5

A-48

MOUNTAIN AREA


PJ
PJ
CF
CF
WC
WC
WC
WC
WC
TC
TC
TC
TC
TC
TC
BANNING
RIVER

ton 1960 VEGETATIVE ZONES: CF - Conifer Forest PJ - Pinyon-Juniper WC - Woodland Chaparral TC - Timberland Chaparral

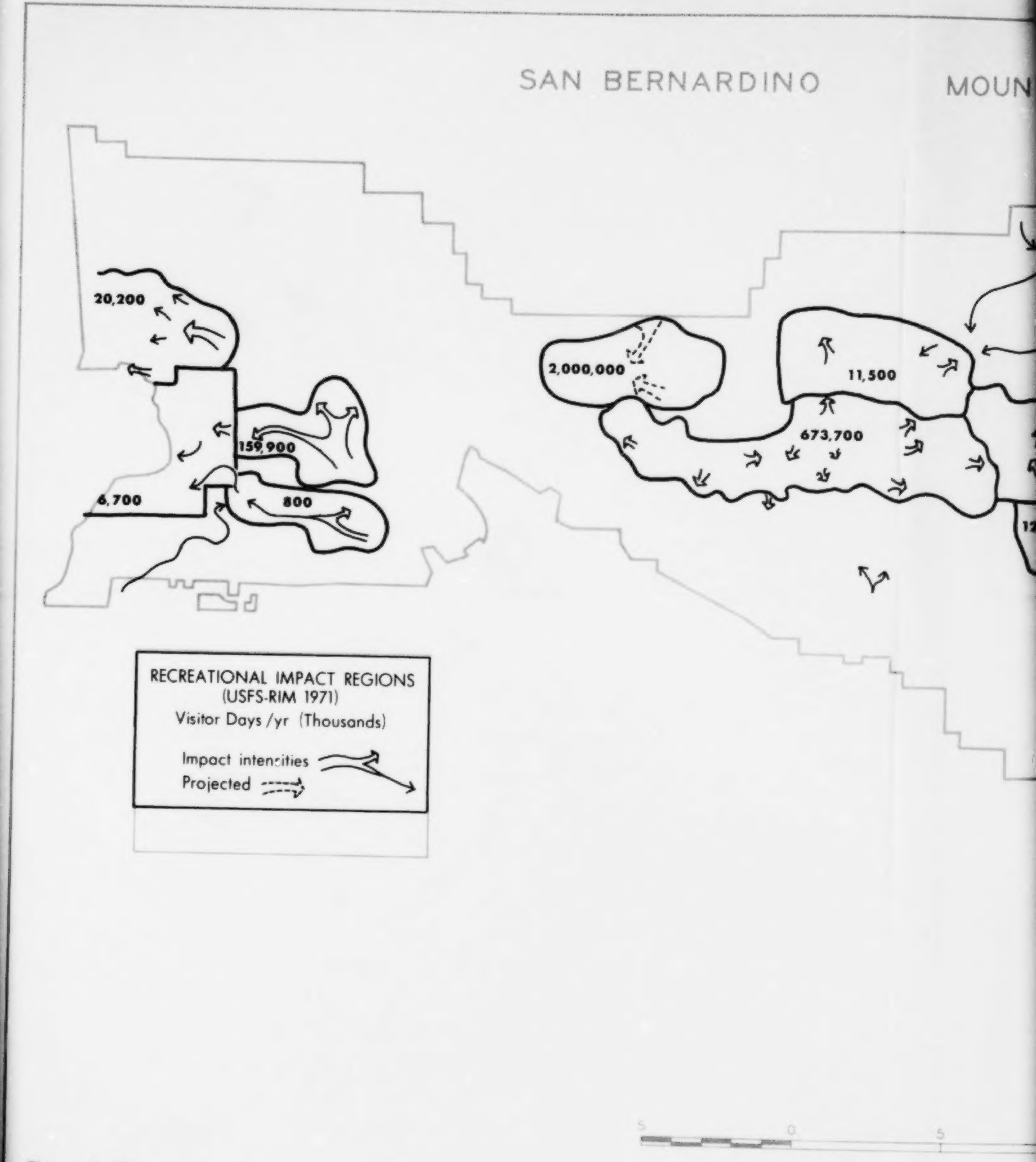
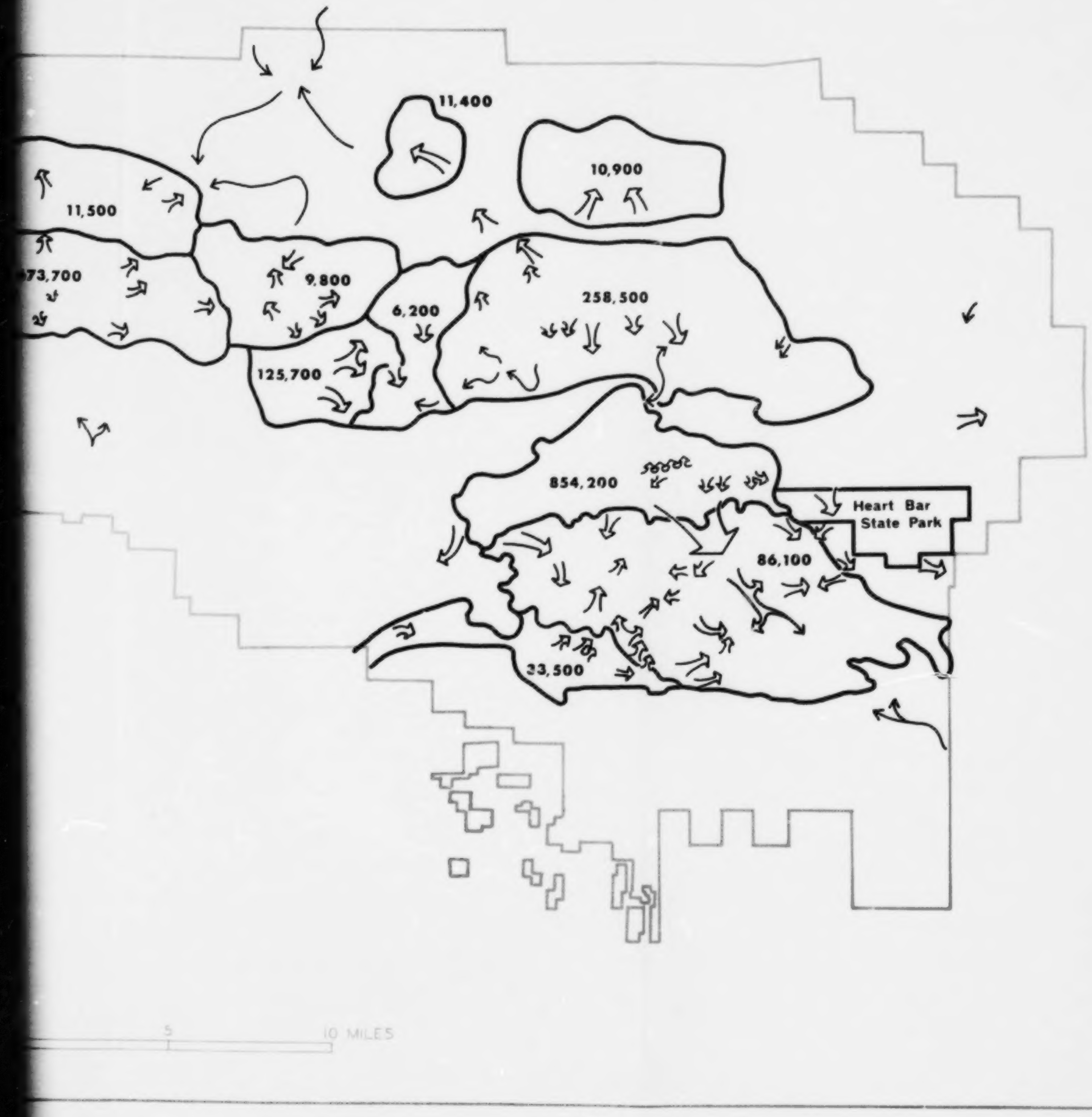

SAN BERNARDINO
MOUN
20,200
159,900
6,700
800
2,000,000
11,500
673,700
12
RECREATIONAL IMPACT REGIONS
(USFS-RIM 1971)
Visitor Days /yr (Thousands)
Impact intensities
Projected
5
0
5

Figure A-6b

O MOUNTAIN AREA


11,400
10,900
11,500
73,700
9,800
6,200
258,500
125,700
854,200
Heart Bar State Park
86,100
33,500
5
10 MILES

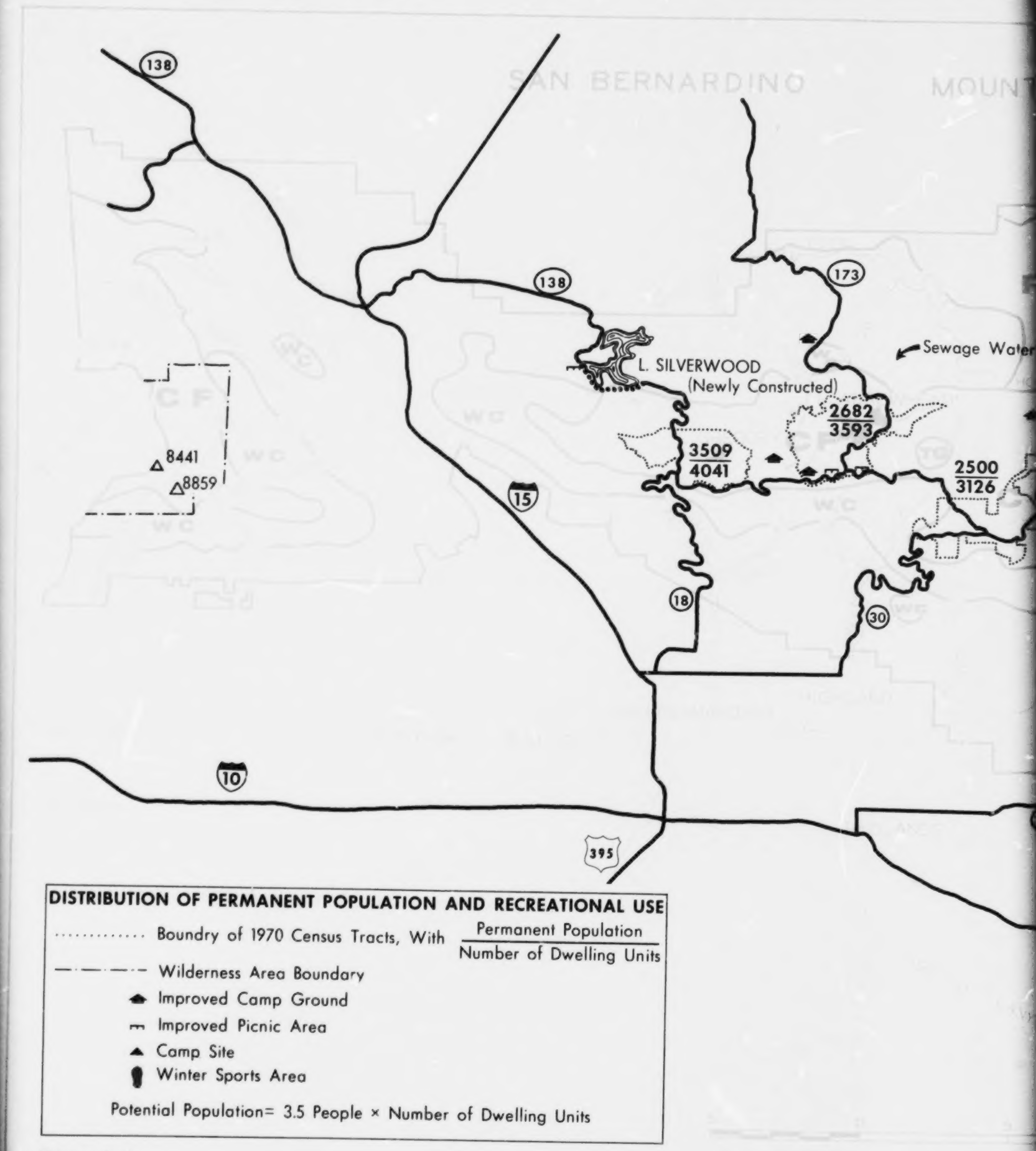
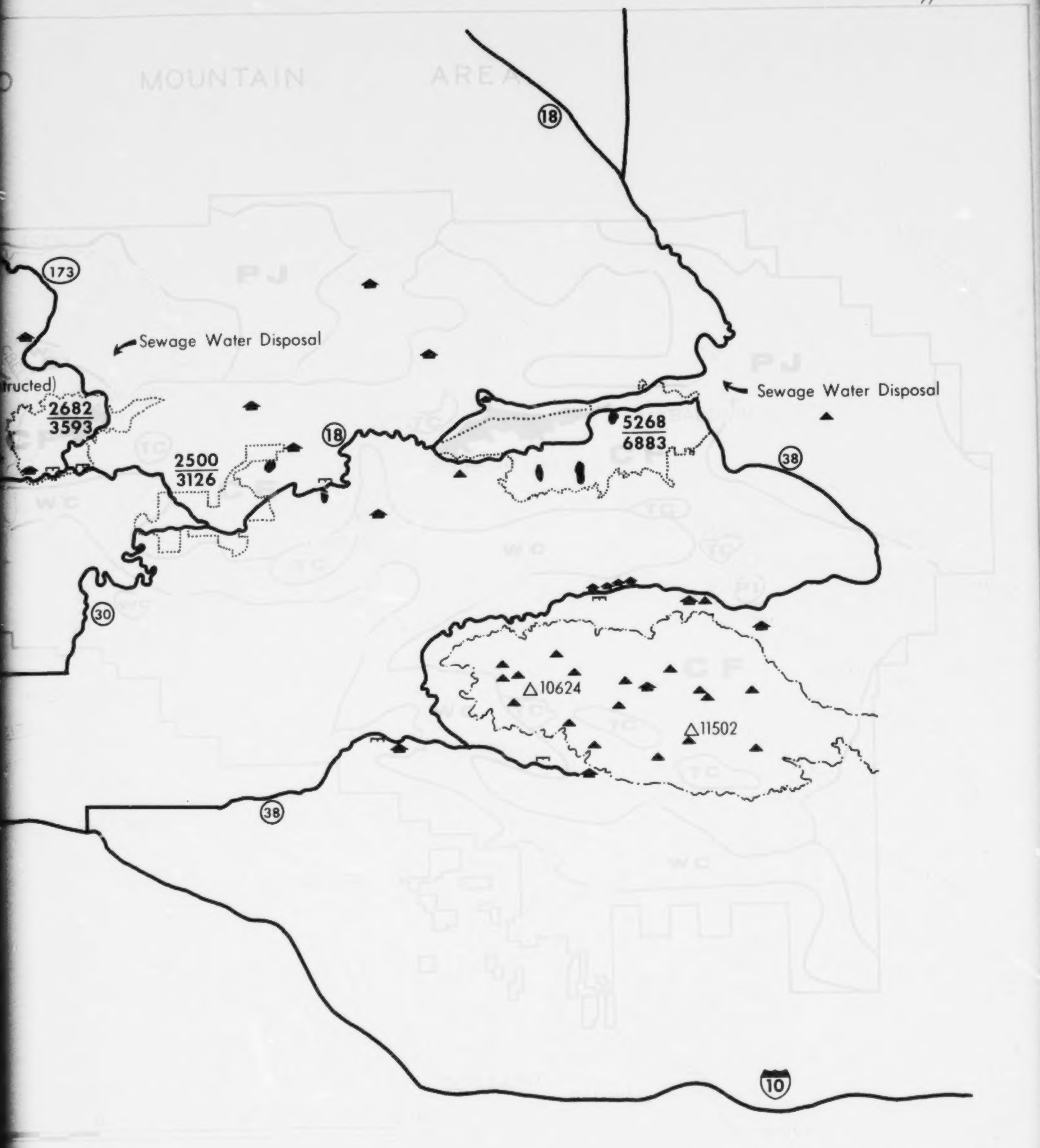

138
SAN BERNARDINO
MOUNT
138
173
Sewage Wate
L. SILVERWOOD
(Newly Constructed)
2682
3593
3509
4041
2500
3126
CF
WC
8441
8859
15
18
30
10
395
DISTRIBUTION OF PERMANENT POPULATION AND RECREATIONAL USE
Boundry of 1970 Census Tracts, With Permanent Population / Number of Dwelling Units
Wilderness Area Boundary
Improved Camp Ground
Improved Picnic Area
Camp Site
Winter Sports Area
Potential Population= 3.5 People × Number of Dwelling Units

Figure A-6

A-50


MOUNTAIN AREA
18
173
PJ
Sewage Water Disposal
tructed)
2682
3593
CF
TC
2500
3126
WC
18
5268
6883
CF
PJ
Sewage Water Disposal
38
TC
WC
30
CF
△10624
△11502
WC
TC
38
WC
10

ortor VEGETATIVE ZONES: CF - Conifer Forest PJ - Pinyon-Juniper WC - Woodland Chaparral TC - Timberland Chaparral

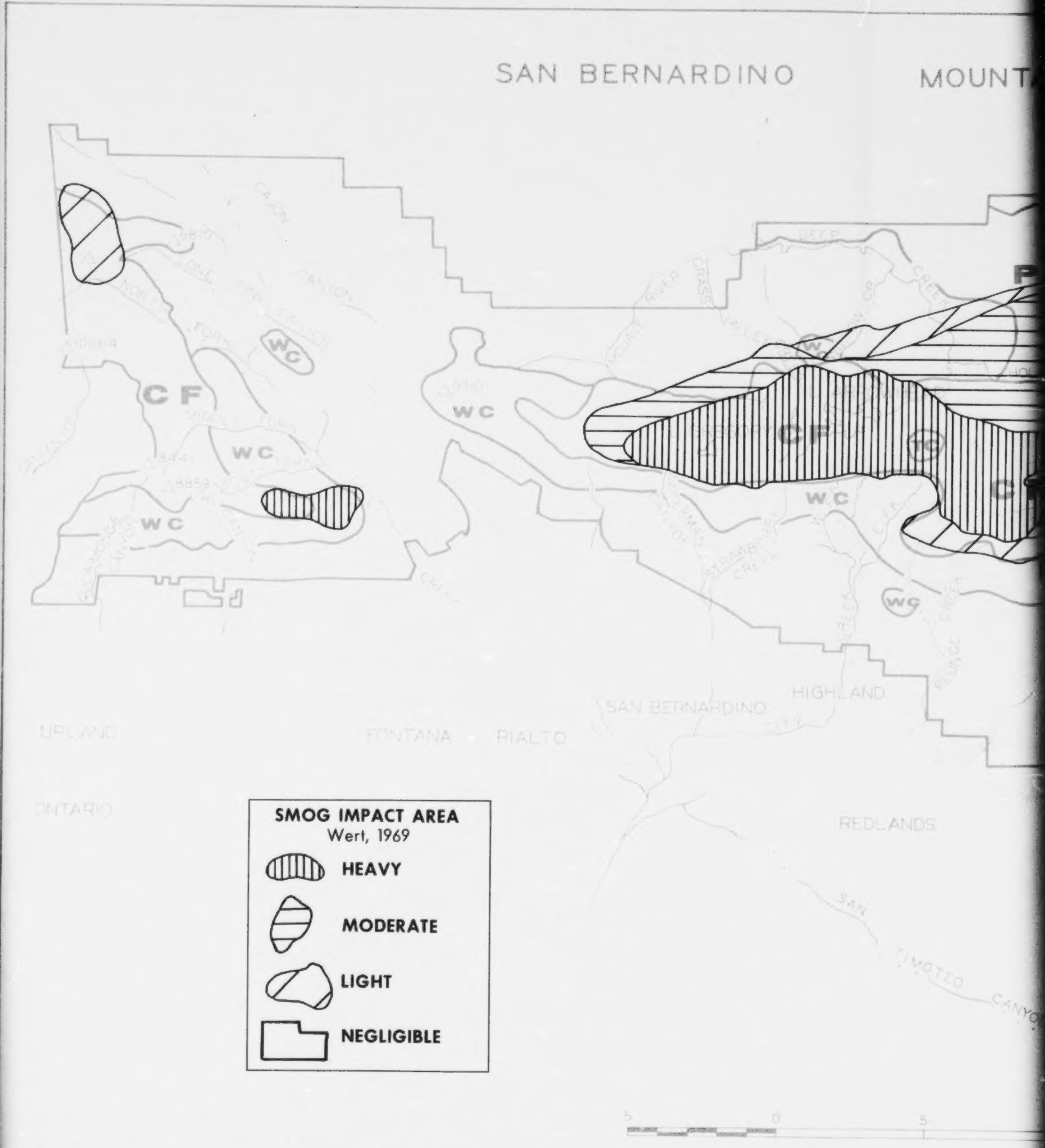
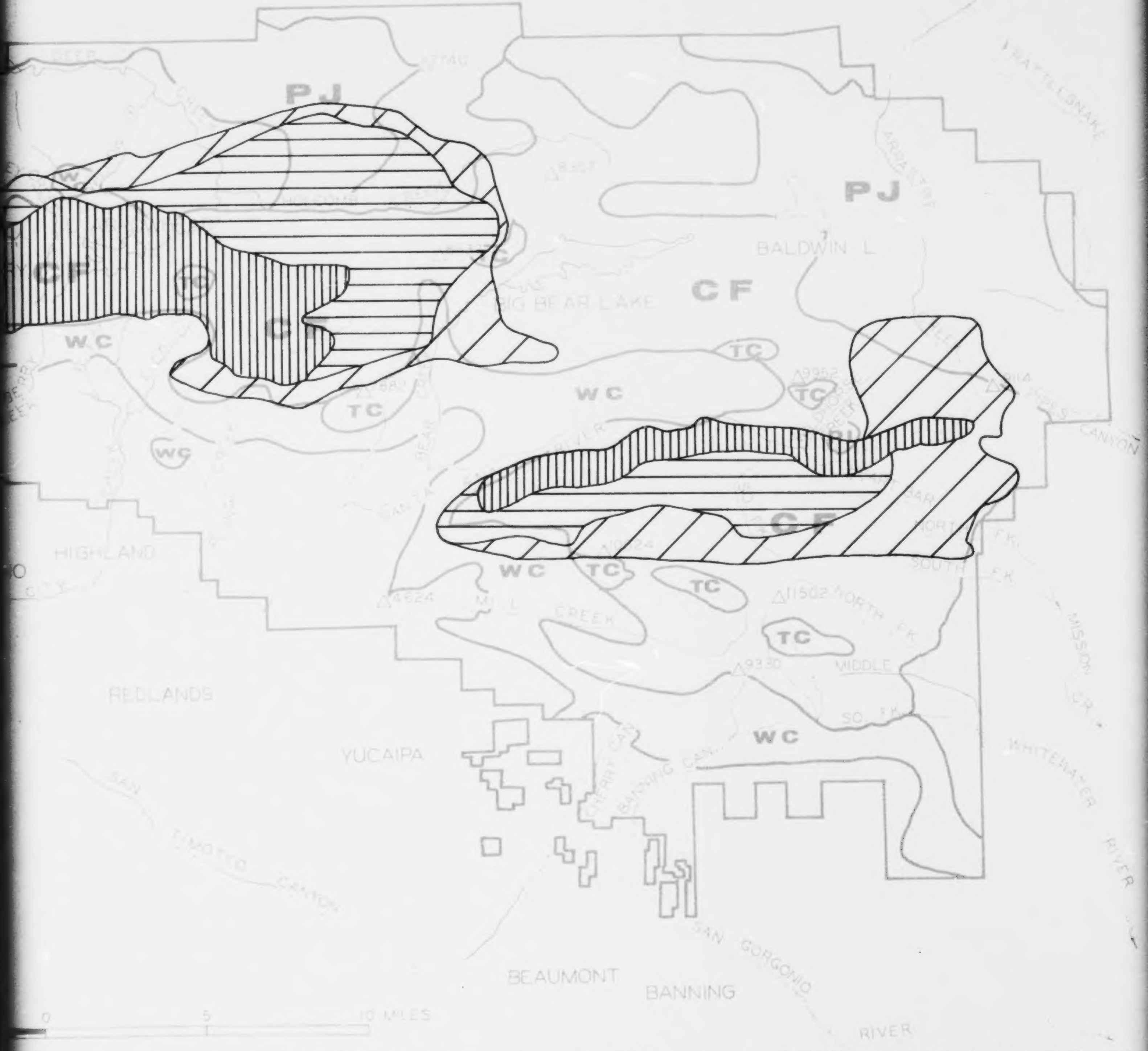

SAN BERNARDINO
MOUNTA
CF
WC
WC
WC
WC
WC
CF
WC
TC
WC
CAJON
CANYON
LONE PINE CANYON
NORTH FORK
MIDDLE FORK
FORK
DEEP CREEK
MOJAVE RIVER
GRASS VALLEY
STRAWBERRY CREEK
CITY CREEK
PLUNGE CREEK
E. FK.
UPLAND
ONTARIO
FONTANA
RIALTO
SAN BERNARDINO
HIGHLAND
REDLANDS
SAN TIMOTEO CANYON
5
0
5
SMOG IMPACT AREA
Wert, 1969
HEAVY
MODERATE
LIGHT
NEGLIGIBLE

Figure A-7

Horton 1960 VEGETATIVE ZONES:

A-60

NO MOUNTAIN AREA


PJ
PJ
CF
CF
CF
CF
WC
WC
WC
WC
WC
TC
TC
TC
TC
TC
TC
TC
HOLCOMB
BIG BEAR LAKE
BALDWIN L
DEEP
CREEK
RATTLESNAKE
ARRASTRE
PIPES
CANYON
7740
8357
9952
10624
11502
9330
4624
SANTA ANA RIVER
BEAR CR
NORTH FK
SOUTH FK
MIDDLE
SO FK
MILL CREEK
HIGHLAND
REDLANDS
YUCAIPA
CHERRY CAN
BANNING CAN
MISSION CR
WHITEWATER RIVER
SAN TIMOTEO CANYON
BEAUMONT
BANNING
SAN GORGONIO RIVER
0
5
10 MILES

Horton 1960 **VEGETATIVE ZONES:** CF - Conifer Forest PJ - Pinyon-Juniper WC - Woodland Chaparral TC - Timberland Chaparral

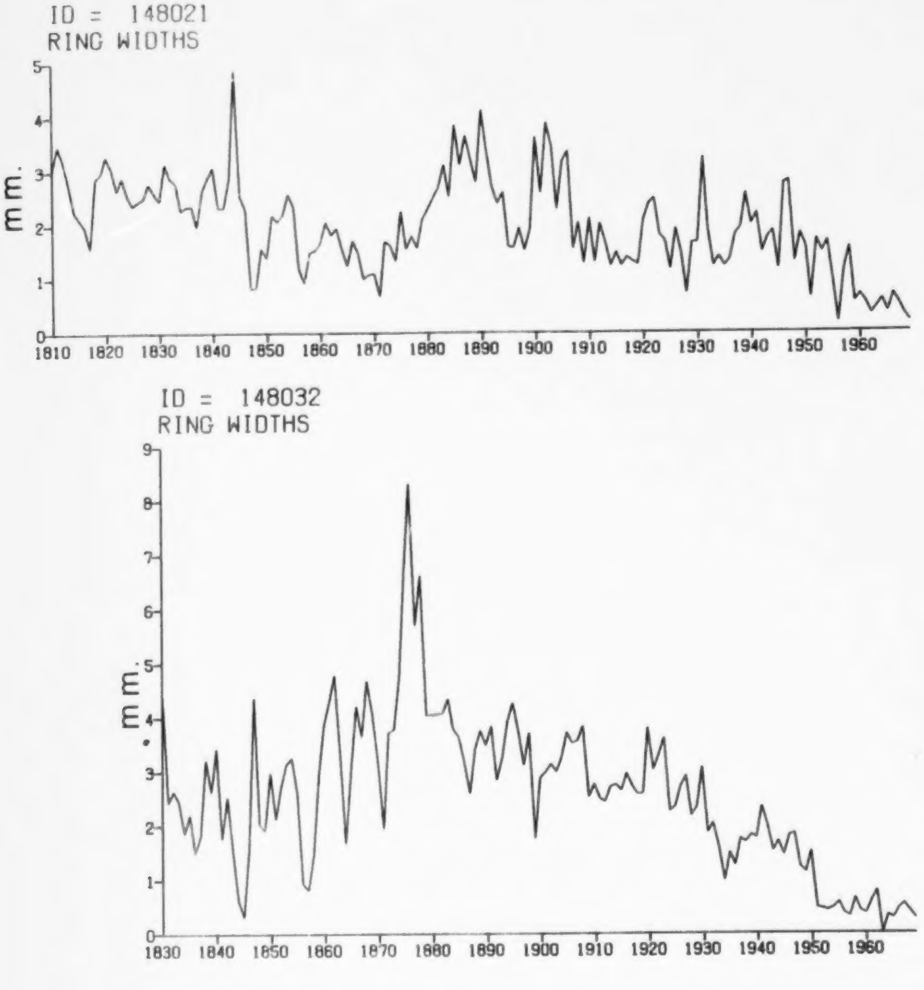


Figure A-8 – Decrease in ring width growth due to air pollution. (Fritts, *In Press*)

SUGGESTED INTERACTIONS OF OXIDANT IN THE FOREST ENVIRONMENT

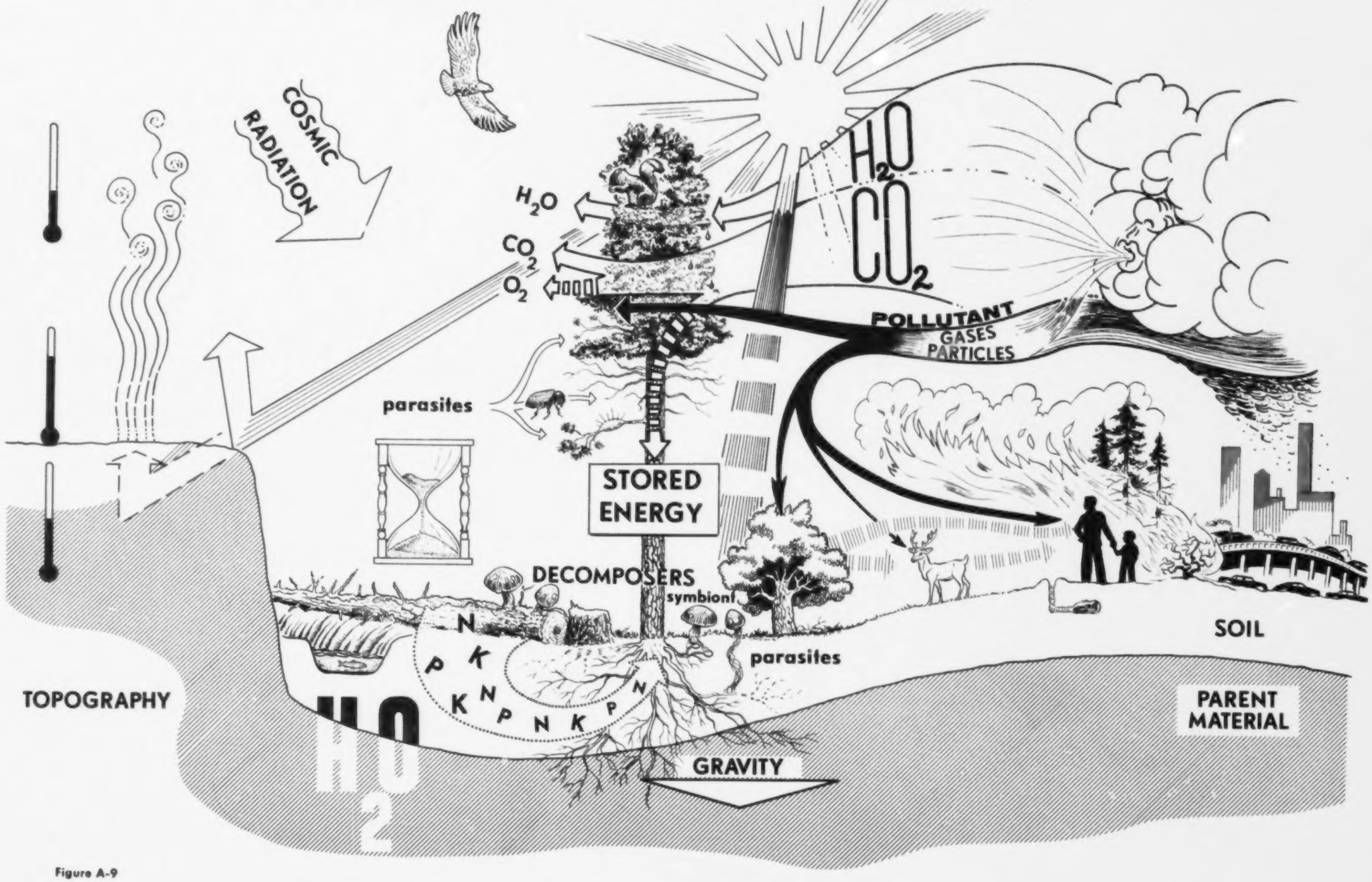

COSMIC RADIATION
H2O
CO2
O2
H2O
CO2
POLLUTANT
GASES
PARTICLES
parasites
STORED ENERGY
DECOMPOSERS
symbiont
parasites
N K P K N P N K P N
H2O
TOPOGRAPHY
GRAVITY
SOIL
PARENT MATERIAL

Figure A-9

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EFFECTS OF OXIDANT AIR POLLUTION ON THE FOREST ECOSYSTEM OF THE SAN BERNARDINO MOUNTAINS

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EFFECTS OF OXIDANT AIR POLLUTION
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VERTEBRATE PATHOLOGY

INTRODUCTION

An ecosystem is composed of four main constituents: abiotic substances, producers, consumers and decomposers (Odum, 1959). This section deals with consumers: vertebrate organisms which are directly or indirectly dependent on producers or vegetation for food and cover. Vertebrates in the forest ecosystem include primary (herbivore) and secondary (carnivore and insectivore) consumers. Primary consumers are grazers, browsers and seed eaters.

The distribution of vertebrates in the forest ecosystem is governed by the availability of water and the quantity and quality of the plants in the system.

Each vertebrate organism occupies a distinct ecologic niche in the forest ecosystem. Difficult to define, a niche may be described as a place in the ecosystem in which a particular vertebrate is bound by its structural adaptations, physiological responses and specific behavior. The specific role of the niche in the ecosystem is not completely understood.

A general listing of vertebrates and their habitat by vegetative types has been compiled by the San Bernardino National Forest in a _Habitat Management Plan, Forest Wildlife_ (Light and Graham, 1968).

History of Vertebrates

Man's attitudes toward the environment have effected the status of vertebrates in the San Bernardino Mountains both directly and indirectly. These attitudes can be divided into eras of impact which have altered the status of vertebrates in the study area.

Era of Abundance (1769-1840)

Man's major concern during this period was survival. The abundance of vertebrates provided the main food supply and depletion of the wildlife by Indians and outpost missions was minimal.

Era of Exploitation (1840-1900)

Extensive mining of the San Bernardino Mountains during this period resulted in large-scale slaughter of deer and bighorn sheep for food. Miners, cattlemen and other residents regularly harvested trout, deer, bighorn sheep, pigeon, quail and other small animals without restriction. Concern over the rapid decline of bighorn sheep led to the first hunting restrictions imposed in 1873, but considerable poaching persisted. Considered a threat to lives and property, the grizzly bear became extinct prior to 1921. However, trout were abundant in the Santa Ana River near the confluence of Bear Creek (LaFuze, 1971) until the early 1900's when natural regeneration diminished because of the damming of the river and the accumulation of sediment loads deposited in the channel. Range lands were heavily used by domestic livestock, thus reducing range carrying capacity and altering the habitat of many species.

The Homestead Act resulted in extensive development of valuable wildlife areas for home tracts and pastures while much land was inundated by reservoirs. Such misuse persisted until informed citizens instituted protective legislation for the conservation of wildlife resources.

Era of Preservation and Propagation (1900-1945)

During this period, numerous regulatory agencies were established by the federal and state government to manage and protect wildlife resources. Their activities included reduction of cattle on depleted range, protection of bighorn sheep, imposition of hunting seasons and bag limits, protection of all scavenger or carrion feeding birds, designation of wildlife refuges and preserves, and protection from wildfire, insects and disease. Various species such as trout (1893), black bear (1934), beaver (1940) and upland game birds were introduced to the San Bernardino Mountains.

Concurrent with these developments, the practices of the logging industry during this period resulted in the conversion of extensive timber area to vegetation favoring game population increases (Miller, 1972).

As a result of all these measures, wildlife populations increased beyond all expections. By the early 1940's, populations of game, primarily deer, had increased beyond range carrying capacity.

Era of Regulated Harvests and Habitat Management (1945-1970)

The increase in game populations during the previous era necessitated a period of control. Studies (Dasmann, 1963; Lounghurst, 1952; Taber, 1958) indicated that management of deer populations and their habitat was essential and that habitat conditions produced by the environment played the major role in game population (Dasmann, 1963). Imbalances resulting from environmental factors such as temperature and amount and distribution of rainfall produce marked fluctuations in wildlife populations.

With hunting restricted by fire closures, limited access, private property, game refuges and firearms closures, habitat management has become the primary method of wildlife control. Habitat management plans, with emphasis on increased availability of water and forage, have been developed by the San Bernardino National Forest Service for the following species:

San Bernardino Deer Herd (Light, 1965)
San Gabriel Deer Herd (Winter and Light, 1965)
Quail (Graham, 1966)
San Gorgonio Bighorn (Light, et al., 1966)
Birds (Graham, 1966)
San Gabriel Bighorn (Light, et al., 1967)
Forest Wildlife (Light and Graham, 1968)
Beaver (Light, 1969)
Fish (Light, 1969)

Coordination of other land uses is now needed if the wildlife resource is to continue its role in the forest ecosystem.

Era of Environmental Concern (1970-)

Beginning in 1970, national attention was focused on the cumulative effects of human activity upon the environment. Concern developed for the perservation of our national resources.

THE VERTEBRATES IN THE ECOSYSTEM

Determining the effects of oxidant air pollution on the vertebrate environment in the Forest Ecosystem requires a thorough inventory of all vertebrates; a life history of each vertebrate type; a determination of the dependency of a vertebrate on a particular community or group of plant communities; and the isolation of all the possible environmental variables affecting the vertebrates.

Inventory of the vertebrates in the San Bernardino Mountains (Light and Graham, 1968) has begun. General life history data on the listed vertebrates is available but not in sufficient detail to relate specifically to the vegetation communities in the San Bernardino Mountains. The vertebrates studied for their life histories which occupy vegetation types in the oxidant air pollution impact zones (P. R. Miller, 1970) are:

Bewick's Wren	(Swarth, 1916)
Brown towhee	(Davis, 1951)
Scrub & Steller's Jays	(Swarth, 1918)
Deer	(Taber and Dasmann, 1958)
Wood Rat	(Horton, et al., 1944)
Mole	(Grinnell and Swarth, 1912)
Chickadee	(Grinnell, 1918)
Nuthatches	(Norris, 1958)
Chipmunks	(Johnson, 1943)
Gnatchatchers	(Grinnell, 1926)
Trout	(Calhoun, 1966)
Turkey Vulture	(Stager, 1964)

Nevertheless, current human activities continue to effect the Forest Ecosystem. Construction of homes and highways is replacing many important wildlife habitats (Aschmann, 1959). Producer plants and primary consumers have been and are continuing to be displaced. Oxidant air pollution emanating from the Los Angeles and San Bernardino basins is having a pathological effect on vertebrates. The users of the homes and highways further contribute to this air pollution. Recreational activities such as shooting, motorcycling, and hiking effect the use of a habitat by both the primary and secondary vertebrates. Vertebrate habitats in the line of sight zone are being displaced as if by the bulldozer.

The cumulative effects of human activity in the Forest Ecosystem are eroding away the habitat of the primary consumer vertebrates such as the deer and the bighorn; deer now being primarily concentrated in areas inaccessible or not often frequented by man (Fig. A6b).

Having put the status of vertebrates in historic perspective, it is now necessary to isolate the major or critical vertebrate species in the ecosystem in order to consider the possible effects of oxidant air pollution on the selected vertebrate species.

The current status of vertebrates is shown on the graphic map of the San Bernardino Mountains (Fig. B1) which indicates locations of selected vertebrates. See the Habitat Management Plan Forest Wildlife (Light and Graham, 1968) for a complete listing of habitat types and vertebrates.

Studies of other species may have been made, but an extensive review of literature will be required to extract them.

The larger mammals and birds of interest to man such as deer, bighorn, gray-squirrel, quail, and pigeon have received extensive study in northern California, but not in the San Bernardino Mountains. Inventories (Light and Graham, 1958) have been made of the above species in the San Bernardino Mountains using behavior and physiological studies made in other areas for comparative analysis in determining habitat management. However, precise physiological (life history) data must be gathered on these vertebrates if the effect of oxidant air pollution is to be determined.

Vertebrate - Vegetative Type Dependency

The dependency of vertebrates on plant communities in the forest biome may be simple or complex. The Vertebrate-Habitat Dependency Matrix (Table B1) (Munnich, 1971; Horton, 1960; Light and Graham, 1968) gives a broad example of the dependency of vertebrates on the various vegetation types which fall within the zone of heaviest oxidant air pollution impact (Miller et al., 1970).

Vertebrate Food Chains

The quantity of vertebrate mass by vegetation types is indicated on the vertebrate - habitat dependency matrix. Another step with respect to each vertebrate's role in a food chain will enable isolation of the ecologically important vertebrate for study. The matrix then provides a source for developing a vertebrate food chain or energy flow chart using the Producer and Consumer constituents of the system.

A simplified vertebrate food chain for larger vertebrates in the black oak woodland vegetative type is:

Consumers:

Secondary: Mountain lion, Man, Audubon's Warbler, Coyote, Bobcat, Red-tailed Hawk

Primary: Gray Squirrel, Deer, Band-tailed Pigeon

Producer : Black Oak mast

More complex vertebrate food chains were derived from the matrix for the pine forest, bigcone Douglas fir and chamise chaparral plant communities of the San Bernardino Mountains and are shown in the Appendix.

From a cursory analysis of the Vertebrate - Habitat Dependency matrix a listing of important vertebrates with significance for the oxidant air pollution study has been devised (Appendix B).

VERTEBRATE PATHOLOGY

The pathological effects of oxidant air pollution on vertebrates has received limited study in the clinical laboratory, but no study of its affects on vertebrates in the wilds has been made.

Oxidant air pollution effects in this discussion are classified as either Direct or Indirect. The Direct effects result from exposure of the vertebrate to ambient air. The Indirect effects result from exposure of both vegetation and vertebrates to ambient air involving a break down in the food chain of a group or particular species of vertebrates.

Direct Pathology

Clinical laboratory research of mice and rats has revealed that ambient air depresses running activity (Emik, et al., 1969; Campbell, et al., 1970), causes an increased susceptibility to pulmonary infection but not to increased pulmonary neoplasia (Gardner et al., 1966, 1970) and promotes the development of a renal (kidney) degenerative disease in male rats (Gardner et al., 1969). These studies also indicated that neoplasia and renal degenerative diseases varied significantly when comparing one strain of mice and rats with another. Such pathological studies have not been performed in the San Bernardino Mountains.

It has been well documented (Gardner, 1966) that photochemical smog will "exert an irritant effect upon human respiratory and ocular mucous membranes". The probability that this could occur with other vertebrates exists. In the San Gabriel Mountains, bighorn sheep, Ovis canadensis nelsoni, have been found to be totally or partially blind from what appears to be cataracts (white blotches in the eyeball). Older bighorn appear to be those effected. This pathological phenomena has been observed only in bighorn in the Lytle Creek and East Fork of the San Gabriel River watersheds of the range where heavy oxidant air pollution occurs.

Air pollution is suspect in causing respiratory ailments in animals. The effect could be particularly acute in animals already suffering a high incidence of respiratory ailments (lungworm-pneumonia complex is common in bighorn sheep) or in animals with a high metabolic rate (swallows, swifts, warblers, etc.).

Peroxyacetyl nitrate (PAN), a common constituent of smog, causes eye irritation in humans. This eye irritation could be far more serious to those vertebrates which depend on their eyesight for survival, such as swallows, eagles and hawks.

Other effects may occur such as interrupted embryo development similar to that which results from Hypoxia. The function of the olfactory gland in vertebrates may be impaired by the ambient air causing a decrease in food-gathering ability, such as in the Turkey vulture (Stager, 1964). Few of the smaller vertebrates (rodents and lizards live more than three years in the wild which will make it difficult to demonstrate any pathological effects of oxidant air pollution (Stewart, 1971).

Indirect Pathology

The effect of air pollution on plant development and succession is extremely important to wildlife. Plants can be adversely affected in many ways, but in general, studies indicate that most plants are affected in a quantitative rather than in a qualitative sense. Growth of truck farm crops such as lettuce and celery and of citrus trees has been retarded due to photochemical reactions resulting from oxidant air pollution (Hindawi, 1970; Jacobson et al., 1970).

The probability exists that certain herbs and shrubs in the forest ecosystem of the San Bernardino Mountains are also effected by oxidant air pollution. Observations indicate a quantitative reduction in growth of chamise leaves, *Adenostoma fasiculatum*, although the nutrient quality of chamise remained the same (Hanes, 1971).

Deer habitat analysis conducted by the San Bernardino National Forest Service indicates that deer use fluctuates with the growth trends of important browse. Any reduction in vegetation growth, either naturally or as a result of ambient air, would have far reaching and subtle effects on vertebrates dependent on annual forage production.

Most vertebrate biologists believe that the primary effects of oxidant air pollution on vertebrates in the San Bernardino Mountains will prove to be exerted indirectly through changes in the vegetation. From an analysis of the vertebrate food chain models of most vegetative types the herbivore vertebrates, including the rodents and ungulates, appear to provide a significant research link. The survival of this group is dependent on the quantitative production of forage plants. The productivity trends of the herbivores will similarly effect the productivity trends of omnivore and carnivore vertebrates who prey on the herbivores.

The probable effects of oxidant air pollution on the aquatic environment would be of an indirect nature. Limited studies have been made of the effect ambient air would have on vertebrates in this environment (Holeton, 1971; Whitworth, 1970). Direct pathologic effects may result from the ingesting of suspended particulate matter arriving in the aquatic environment from the atmosphere through precipitation (Whitworth, 1970). Indirect pathological effects on coldwater fish, which predominate in the San Bernardino Mountains, may result from the loss of vegetation, thereby causing an increase in water temperatures, a reduction in dissolved oxygen, an increase in biological oxygen demand, and a reduction of desired aquatic insects which serve as food. Research should be directed toward an entire aquatic ecosystem located in the ambient air impact zones as described by P. R. Miller (1970).

SUMMARY & RECOMMENDATIONS

An inventory of animals existing in the San Bernardino Mountain area has been made and their habitat relationships to plant communities is fairly well known. However, the details of each species' ecologic niche and their dependency on certain vegetation is only partially understood. The role of each species in the ecosystem is only basically known (Primary consumer, secondary consumer). Food habits are known in detail for only a few species.

Present knowledge of the physical effects of oxidant air pollution on the animals themselves can be derived only sketchily from limited research on laboratory animals. Nothing is known about the multitude of possible effects from injury by oxidant air pollution to green plants (producers) and the habitat changes that may then gradually occur. It is easy to speculate about changes in quality of forage for ruminants; quantity of food for seedeaters; plant succession and food availability for animals with specific food requirements; insect abundance; litter accumulation for shelter of small mammals and reptiles; and microclimatic changes. Hard facts, obtained by well-directed, intensive research, are badly needed to measure the magnitude of the environmental change, both existing and potential.

More precise information on all variables effecting important systems of vertebrates is needed. Most vertebrate biologists agree that precise inventories of all vertebrates need to be made in the oxidant air pollution impact areas (Miller, 1970). Once this is accomplished, the effects of oxidant air pollution on vertebrates can then be measured. Most contributors expressed the need to establish a baseline (or control) forest ecosystem not influenced by oxidant air pollution in order to compare the effects of ambient air on the vertebrates.

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TABLE B1

VERTEBRATE - HABITAT DEPENDENCY MATRIX

Resident Vertebrates[I]	Habitats[II] CS	Cs	CH	CsJ	CWD	CFhs	CFco	CFcp	CFkw	OF	TF	PF	PFM	CT	R	G	LP	Eco[IV] Role
MAMMALS																		
Mole, California																3		O
Shrew, Dusky																3		I
Myotis, Fringed						1	2								3			I
Myotis, California						3	1								2			I
Bat, Hoary						3	1								2			I
Bat, Western Red						1	2								3			I
Bat, Lump-nosed					1	2	3											I
Bat, Pallid					2	3	1											I
Ground Squirrel, California				1			2									3		H
Ground Squirrel, Goldmantled										1		3				2		H
Chipmunk, Lodgepole												1					3	H
Chipmunk, Merriam							1					3	2					H
Gopher, Botta pocket												2			3	1		H
Mouse, Little pocket				1	2		3											H
Mouse, White-eared pocket																3		H
Mouse, San Diego pocket					1	2	3											H
Mouse, California pocket												3	2		1			H
Kangaroo Rat, Pacific				3			2									1		H
Mouse, Western Harvest							2								1	3		H
Mouse, Canyon			1		3		2											O
Mouse, Brush		2	1		3													H
Woodrat, Dusky-footed		1	2		3													O
Meadow Mouse, California															2	3		H
Jack Rabbit, Black-tailed	3	2	1															H
Cottontail, Audubon	3	2	1															H
Rabbit, Brush		3	2		1													H
Gray Squirrel										2		2	1					H
Flying Squirrel, Northern										1		2	3					H
Beaver, Golden															3			H
Raccoon															3			H
Ringtailed Cat				1	3		2											O
Weasel, Long-tailed	1											3				2		C
Skunks															3			C
Badger				2						1		1				3		O
Fox, Gray				2	3					1								O
Coyote	1	1	1	1		3	1	1	1	1		1	1	1	1			O
Bobcat		1		2		3				1		1						C
Bear, Black							1									3	2	O
Lion, Mountain		1			1	3	1			2		1		1	1		1	C
Deer, Mule		1	1	3	1	1								2	1	1		H
Bighorn sheep																	3	H
Total[III] Mass	8	15	10	16	24	25	30	1	1	10	0	25	9	6	29	31	9	
REPTILES & AMPHIBIANS																		
Lizards																		
Western Fence Lizard	1	1	1	1						1				1				I
Sagebrush Lizard										2		3		1				I
Side-blotched Lizard				1								3			2			I
Granite night Lizard										3		2		1				I
Western Skink										1		2			3			I
Gilbert's Skink										1		2			3			I
Western Whiptail						3	1								2			I
Foothill Alligator Lizard					2		3			1								I
California legless Lizard										2		3			1			I
Snakes																		
Rubber snake															3			I
Ringnecked snake						3	2								1			I
Yellow-bellied racer										3					2	1		C
California King snake						2	3								1			C
Mtn. King snake						1				3		2						C
Striped whipsnake				1		2				3								C
Common whipsnake		2	3		1													C
Gopher snake	1	1	1	1	1	1	1	1	1	1								C
Pacific Garter	3														2			C
Rattlesnake	1	1	1	1		1				1		1			3			C
Western Garter						2				1					3			C
Amphibians																		
Eschscholtz's Salamander										1					3			I
S. California Salamander										1					3			I
W. Spade Foot						1	2								3			I
Western Toad										1					3			I
Pacific Tree Frog										1					3			I
Canyon Tree Frog						1									3			I
Red-legged Frog										1					3			I
Yellow-legged Frog															3		2	I
Bull Frog										1					3			I
Total[IIIa] Mass	6	5	6	5	4	17	12	1	1	23	0	21	0	3	53	1	2	

I - (Light & Graham, [illegible]) 1-rare, 2-fairly common, 3-abundant
II - (Minnich, 1971 and Horton, 1960)
III - Mammal Mass
IIIa - Reptile and Amphibian Mass
IV - H-Herbivore, I-insectivore, O-Omnivore, C-Carnivore

TABLE B1 (cont'd)

VERTEBRATE - HABITAT DEPENDENCY MATRIX

Vertebrates[I]	Habitats[II] CS	C	CH	CSD	CMD	CIbs	CFco	CFcp	CLkb	DF	TF	PF	PFM	CT	R	G	LP	Fe Ro
BREEDING BIRDS																		
Audubon's Warbler												3						I
Black-chinned Sparrow	2	3												2				I
Black-throated Gray Warbler						3								3				I
Bluebird, Western										2	2	3	2		3			I
Bush-tit, Common			3	2											1			C
Chickadee, Mountain						1				2		3	3					I
Creeper, Brown										1		3	2					[illegible]
Crossbill, Red											2	2						H
Dipper															3			I
Dove, Mourning		2			1										3			H
Eagle, Golden						3						2			1			C
Finch, Cassin's												3					2	O
Finch, House	3	3	3		2		2								3			H
Finch, Purple							3								3			M
Flicker, Redshafted										3		3			3	2		I
Flycatcher, Ash-throated		2	3				3			2					3			I
Flycatcher, Dusky										1			2	3			2	I
Flycatcher, Olive-sided										1			3	2				I
Flycatcher, Western															3			I
Gnatcatcher, Blue-gray		1	2		3										2			I
Goldfinch, Lawrence's		2			3										2	1		H
Goldfinch, Lesser	2	3			2										3			H
Hawk, Cooper's					3	3		1							3			C
Hawk, Red-tailed		1				3				2		3	1	1		1		C
Hawk, Sparrow	2	2			1					2		2			3	3		CA
Hummingbird, Calliope												3			3			H
Hummingbird, Anna's	3	3	2		3									2				
Jay, Scrub	2	3	3	2	3		1								2			O
Jay, Steller's										3	3	3	3					O
Junco, Oregon												3			2	2	2	O
Kinglet, Ruby-crowned												3						I
Kinglet, Golden-crowned												2					2	I
Lazuli Bunting	2	3												2	3			H
Martin, Purple						3						2			1			I
Nutcracker, Clark's												2	1				3	H
Nuthatch, Pigmy										3	3	3	2					O
Nuthatch, Red-breasted												2						O
Nuthatch, White-breasted										3	3	3	1					O
Orange-crowned Warbler														2	3			I
Owl, Great-horned										3		3			2			C
Owl, Long-eared					3	2												C
Owl, Pigmy						3				2		2			1			[illegible]
Owl, Saw-whet										1		3						I
Owl, Screech							3			2					3			C
Owl, Flammulated												3	3					C
Owl, Spotted						2				3		1						C
Phoebe, Black															3			I
Pigeon, Bandtailed						1				3					2			H
Poorwill	1	3		2														I
Quail, California																3		H
Quail, Mountain				3										2	1			H
Roadrunner		3														2		C
Robin												3	3		3			O
Sapsucker, Williamson's												3	1				2	H
Sapsucker, Yellow-bellied							3					3			2			I
Solitaire, Townsend's												3		2				H
Solitary Vireo							3								3			I
Sparrow, Lark		1														3		O
Sparrow, Rufous-crowned	3	2																H
Sparrow, Sage (Bell)	2	3																H
Swallow, Violet-green						1						3					3	I
Thrasher, California	3	3	1	1														O
Titmouse, Plain				1	3		3							2				O
Towhee, Brown		3	1	2			1											O
Towhee, Green-tailed	3													3				H
Towhee, Rufous-sided	1	3	2	3	2	1									3			O
Warbling Vireo															3			I
Western Tanager						3						3			3			O
Wilson's Warbler															3			I
Woodpecker, Acorn						3				3		2						K
Woodpecker, Downy															3			I
Woodpecker, Hairy						1				3		3			2			I
Woodpecker, Nuttall's					2	3				1					3			O
Woodpecker, White-headed										1	2	3						O
Wren, Bewick's	3	3	2	1											3			I
Wren, House		1		2	3										3			I
Wrentit	2	3								2					1			O
Yellow Warbler															3			I
Total[III] Mass	35	55	22	19	35	36	22	1	0	48	15	62	27	26	103	16	16	

I - (Light & Graham, 1968) 1-rare, 2-fairly common, 3-abundant

II - (Minnich, 1971 and Horton, 1976)

Habitat types

CS-[illegible] Sage Scrub
C-[illegible]
CH-[illegible]
CSD-[illegible]
CMD-[illegible]
[illegible] Douglas Fir
[illegible]

CFco-Conifer [illegible] Dominant
CIbs-[illegible] Pine Dominant
DF-[illegible]
CT-[illegible] Conifer Forest
PF-[illegible]
PFM-[illegible]
[illegible]

R-Riverine
G-Grassland
LP-[illegible] Forest

III - [illegible]

IV - [illegible], I-Insectivore, O-Omnivore, [illegible]

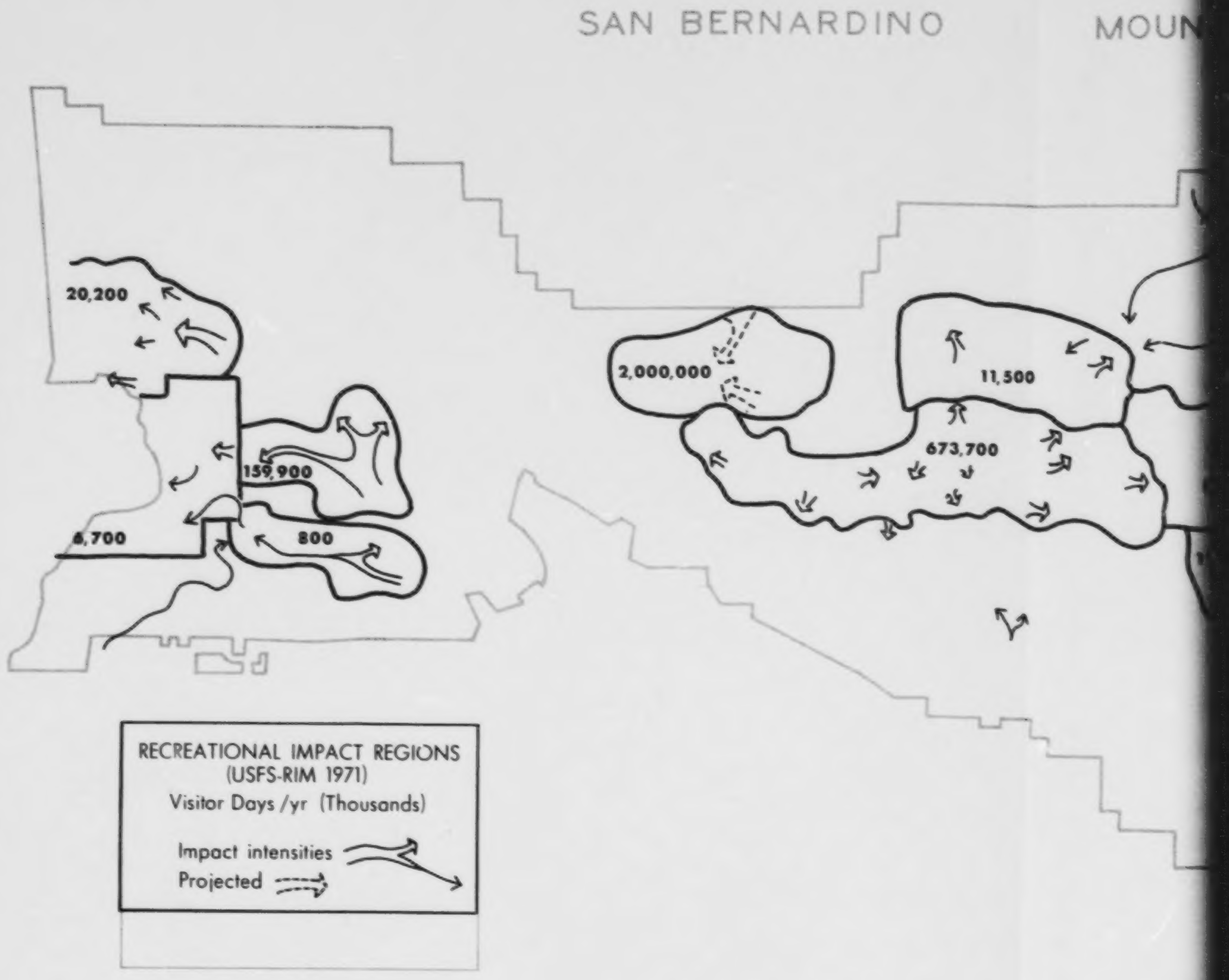
SAN BERNARDINO
MOUN
20,200
2,000,000
11,500
673,700
159,900
6,700
800
RECREATIONAL IMPACT REGIONS
(USFS-RIM 1971)
Visitor Days /yr (Thousands)
Impact intensities
Projected
5
0
5

Figure B-1a

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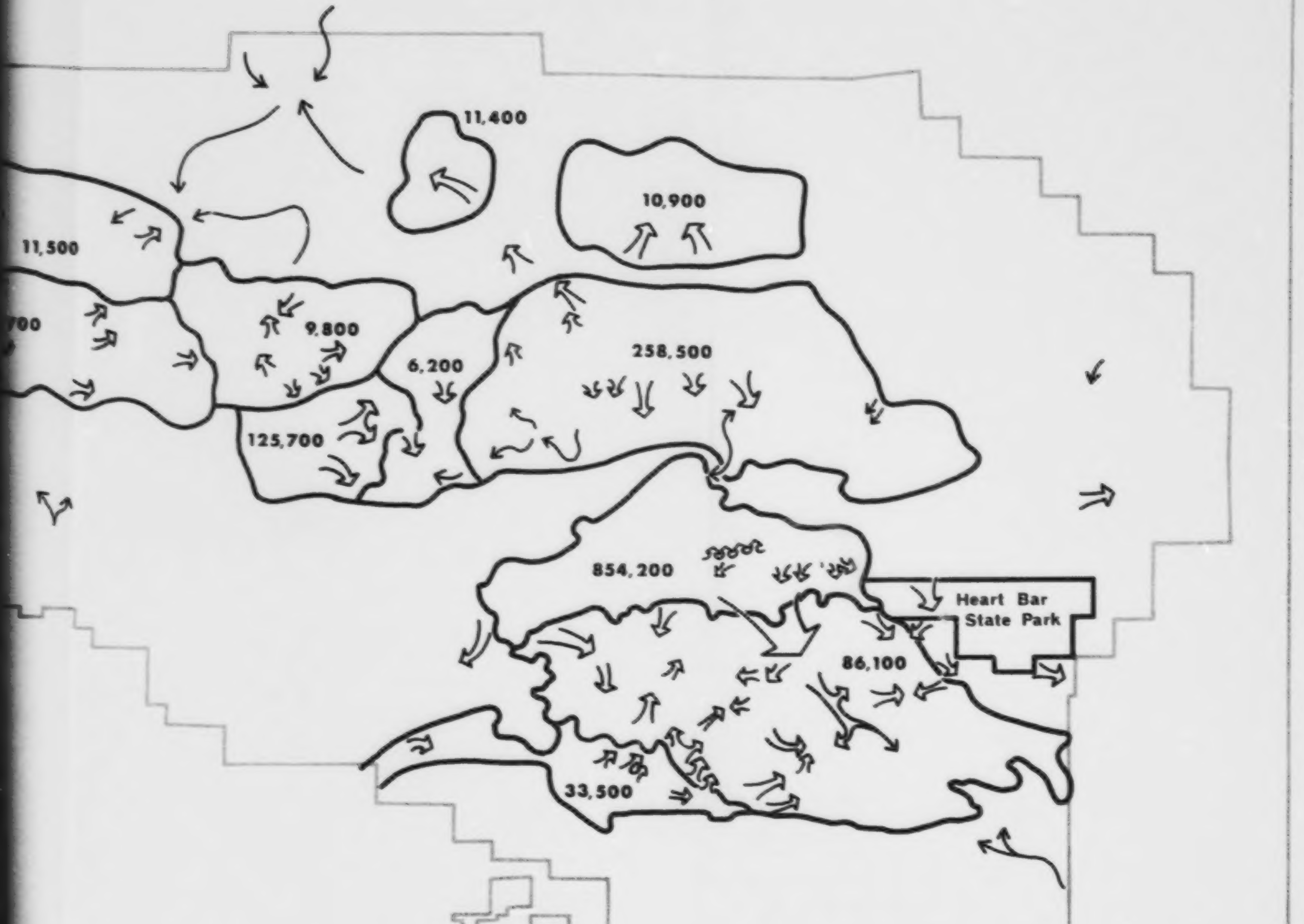
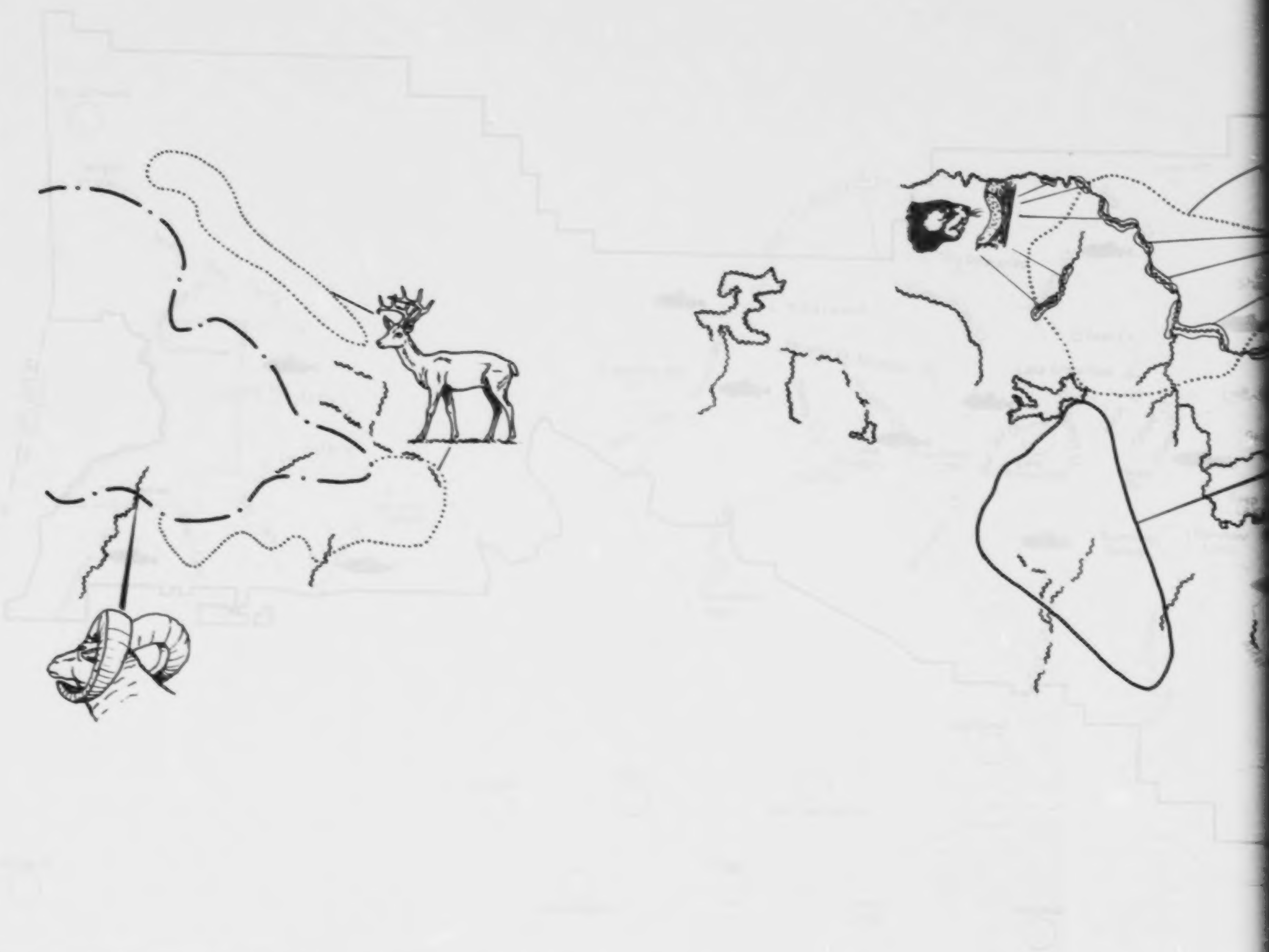
MOUNTAIN AREA


11,400
10,900
11,500
700
9,800
6,200
258,500
125,700
854,200
Heart Bar State Park
86,100
33,500
5
10 MILES



IMPORTANT VERTEBRATES
OF THE
SAN BERNARDINO MOUNTAIN AREA

SAN BERNARDINO NATIONAL FOREST
FISHERY AND WATERSHED MAP

~ ~ ~ Fishery Stream (STOCKED)
~~~~ Fishery Stream (WILD)
Forest Boundry
Wilderness Area

0 1 2 3 4 5 6
scale

Figure B-1
~~~~

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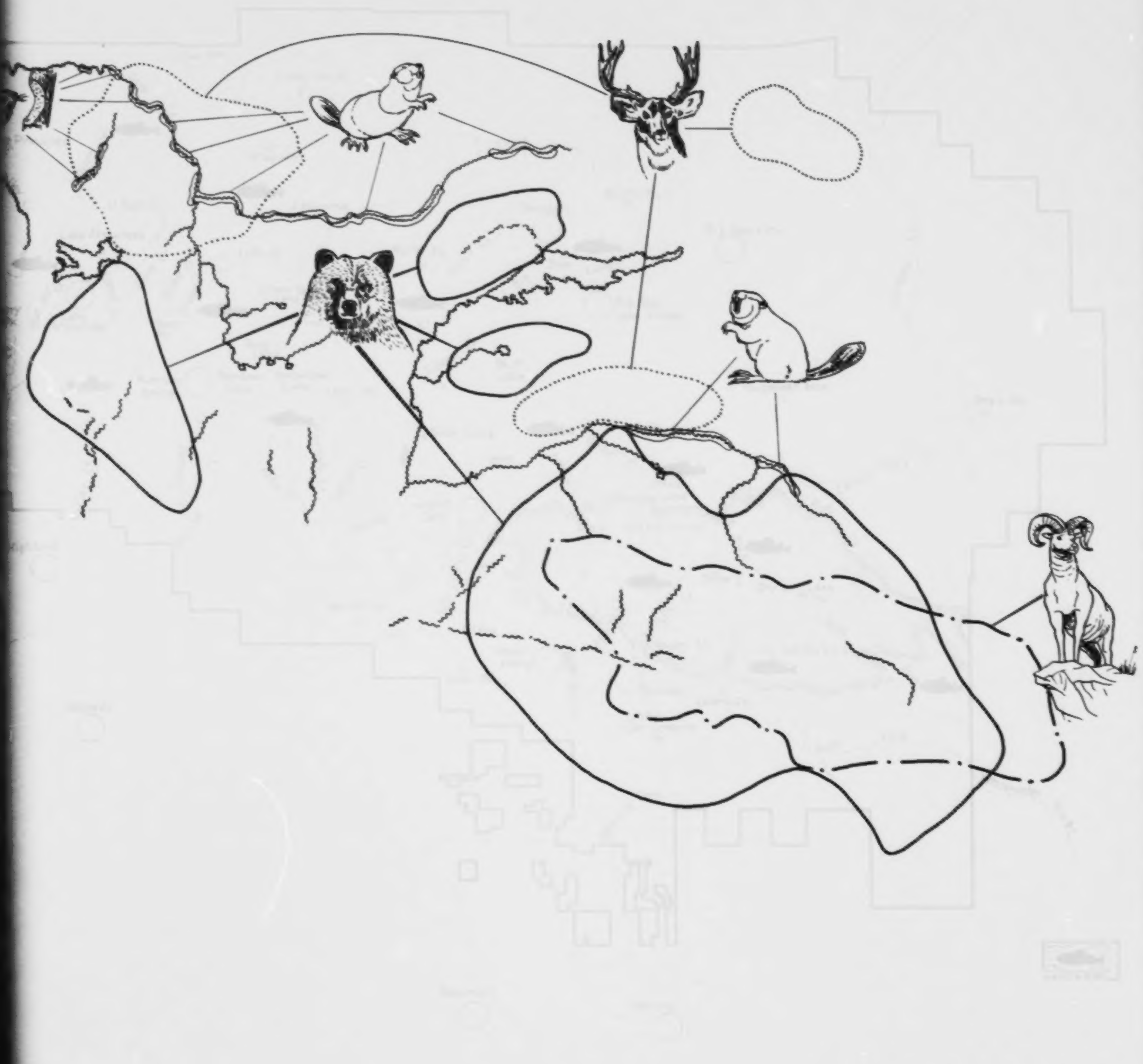

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Appendix: VEGETATION TYPE TABLES

Listing of Key Wildlife Plants: Their Wildlife Values* and Management

CHAMISE-CHAPARRAL ZONE

- Pure Chamise Chaparral Type
- Chamise-Ceanothus Chaparral Type
- Chamise-Manzanita Chaparral Type
- Scrub Oak Chaparral Type
- Coastal Sagebrush Type

WOODLAND-CHAPARRAL ZONE

- Live Oak Chaparral Type
- Live Oak Woodland Type
- Bigcone Douglas fir Forest Type
- Knobcone Pine Forest Type

DESERT CHAPARRAL ZONE

- Desert Chaparral Type

PINYON-JUNIPER WOODLAND ZONE

- Pinyon-Juniper Woodland Type
- Great Basin Sagebrush Type

TIMBERLAND CHAPARRAL ZONE

- Timberland Chaparral Type

CONIFEROUS FOREST ZONE

- Pine Forest Type
- Ponderosa Pine - White Fir Forest Type
- Sugar Pine - White Fir Forest Type
- Grassland Type
- Black Oak Woodland Type
- Alpine Forest Type
- Barren Areas

RIPARIAN WOODLAND TYPE

OTHER IMPORTANT WILDLIFE PLANTS

* Protein values given in the following tables indicate the range which starts high in the spring and drops to the low in winter.

PURE-CHAMISE CHAPARRAL TYPE	Location: Principally found in areas of low rainfall such as foothills on coastal side of mountains, Cajon Pass and W.Fk. of Mojave River. From low levels to 5,500 feet on south-facing slopes. Climate: Rainfall: 13 to 25 inches Growing season: 8 to 12 months Mean summer max: 82°-94° Mean winter min: 29°-45°	Other Classifications: Chaparral (Munz) Transition and Mountain Climatic Zone Lower and Upper Sonoran Life Zones
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: CHAMISE Adenostoma fasciculatum (In this type chamise comprises 75% or more of the composition of the stand. From San Gorgonio Pass south, red-shank (Adenostoma sparsifolium) may replace chamise in this type.)	Food Seeds - important food of Lawrence goldfinch (5-10% of diet) Flowers - woodrat Browse - poor producer of vital protein (6 to 14%) but relatively good source of maintenance energy for browsers-rates fair to good as feed for deer. Cover Good except for roosting	Areas of this type are more productive when opened up and interspersed with perennial grasses which provide the protein lacking in chamise. Islands should be left if better cover species are not available. Because of the arid location water is often needed.
OTHER SPECIES IN TYPE: WHITE SAGE Salvia apigna CALIFORNIA SCRUB OAK Quercus dumosa BIGBERRY MANZANITA Arctostaphylos glauca EASTWOOD MANZANITA Arctostaphylos glandulosa	These species occur scattered and together make up less than 25% of this type. In this type their primary value is that they add variety. Food Seeds - berries and acorns Cover Fair to good	Leave for cover in small islands. Since all these except Sage are "hard" species and chamise is relatively soft; this type can be converted economically with a double-disc treatment of the chamise while skipping the other species.

CHAMISE-CEANOTHUS CHAPARRAL TYPE	Location: Most widespread type on the coastal side of the mountains, however not found in Cajon or Lone Pine Creeks or in the desert drainages; rarely over 4,000 feet. Generally indicates better site than Pure Chamise Chaparral type. Climate: Rainfall: 13 to 35 inches Growing season: 8 months Mean Summer max: 82°-94° Mean Winter min: 29°-45°	Other Classifications: Chaparral (Munz) Transition Climatic Zone Upper Sonoran Life Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: CHAMISE Adenostoma fasciculatum ± 40%	Food Seeds - important to Lawrence goldfinch (5-10% of diet) Flowers - Woodrats Browse - poor producer of vital protein (4 to 14%) although it provides minimum energy requirements for deer.	Chamise is less valuable than Ceanothus which is co-dominant in this type. This type represents a good site for conversions, stoniness and slope permitting.
HOARYLEAF CEANOTHUS Ceanothus crassifolius ± 40% In some places replaced by: CHAPARRAL WHITETHORN Ceanothus leucodermis	Food Seeds - in diet of quail, woodrats, ground squirrels Browse - important to cottontails; fair to good protein supply (11-15%) and preferred by deer; rated good to excellent. Cover Excellent, especially the thorny C. Leucodermis	Ceanothus is more desirable than chamise. In conversion projects and wildlife feed openings, the Ceanothus should be selected for the islands to be retained.
OTHER SPECIES IN TYPE: CALIFORNIA SCRUB OAK Quercus dumosa ± 20%	Food Acorns - highly valued for many species of mammals and birds. Significant in diet of bandtailed pigeon (10-25% of diet), quail (5-10% fragments), redshafted flicker (5-10%), jays (25-50%), rufous-sided towhee (5-10%), plain titmouse (5-10%), California thrasher (2-5%), raccoon (5-10%), pocketgopher (10-25%), mule deer (10-25% in winter). Acorns are low in protein but high in fats and carbohydrates and good energy producers. Browse - Protein levels 16 to 23% in spring, drops to 8% in mature foliage. Accounts for 10-25% of diet of mule deer in some localities, up to 50% in spring. Cover Excellent for most species.	In this type, scrub oak is a valuable shrub to retain for its high wildlife values.
TOYON (Christmasberry) Photinia arbutifolia	Food Berries - taken by many birds in small amounts: Wrentit (2-5% of diet) also bandtailed pigeon, redbreasted sapsucker, California thrasher. Browse - little used when mature Cover Larger specimens (8-10') provide good roosting cover	Occasional specimen shrubs should be retained.
SUGARBUSH Rhus ovata	Food Fruit - taken by many birds and small mammals, especially bandtailed pigeon (2-5% of diet), mountain quail (2-5%) Cover Excellent	Retain occasional specimen shrubs.

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CHAMISE-MANZANITA **CHAPARRAL TYPE**	Location: Less extensive than Pure-Chamise or Chamise-Ceanothus Chaparral but of widespread occurrence above 2,500 feet. Density of manzanita varies from heavy to scattered. Bigberry manzanita is usually at lower elevations and at Cajon Pass (more arid sites). Eastwood manzanita is mostly on the coastal slopes above 4,000 feet. Climate: Rainfall: 13 to 35 inches Growing season: 8 months Mean summer max: 82°-94° Mean winter min: 29°-45°	Other Classifications: Chaparral (Munz) Transition and Mountain Climatic Zone Upper Sonoran Life Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: CHAMISE Adenostoma fasciculatum	Food Seeds - important food of Lawrence goldfinch (5-10% of diet) Flowers - woodrats Browse - poor producer of vital protein (4-15%) but relatively good source of maintenance energy for deer-rates fair to good for feed. Cover Good loafing and escape; poor roosting.	Where slope and soil conditions permit conversion, perennial grass will normally be more productive than this type for most wildlife. A few islands should be retained for variety and cover.
BIGBERRY MANZANITA Arctostaphylos glauca EASTWOOD MANZANITA Arctostaphylos glandulosa	Food Berries - taken by many birds and mammals, California skunk (2-5%), and jays, mockingbirds, raccoons, ground squirrels, black bear, coyotes, etc. Browse - although taken some by deer, manzanita is a poor source of protein (5% or less) and has few redeeming characteristics for forage; rated poor. Cover Often forms tall, impenetrable thickets - excellent for escape.	May be used for islands for escape cover and for the berries.
OTHER ASSOCIATED SPECIES: HOARYLEAF CEANOTHUS Ceanothus crassifolius Usually associated with bigberry manzanita CHAPARRAL WHITETHORN C. leucodermis May be associated with either species of manzanita	Food Seeds - in diet of quail, woodrats, ground squirrels. Browse - important in diet of cottontail, fair to good protein supply (11-15%) and preferred by deer; rated good to excellent. Cover Excellent	Preferred "leave" species for islands in conversion in this type.

SCRUB-OAK CHAPARRAL TYPE	Location: On north-facing slopes mostly above 4,000 feet to 5,500 feet Climate: Rainfall: 20 to 35 inches Growing season: 8 months Mean summer max: 82°-90° Mean winter min: 29°-40°	Other Classifications: Chaparral (Munz) Mountain Climatic Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: CALIFORNIA SCRUB OAK Quercus dumosa	Food Acorns - highly valued for many species for mammals and birds. Significant in diet of bandtailed pigeon (10-25% of diet), quail (5-10% fragments), redshafted flicker (5-10%), jays (25-50%), plain titmouse (5-10%), California thrasher (2-5%), raccoon (5-10%), pocketgopher (10-25%), mule deer (10-25% in winter). Acorns are low in protein but high in fats and carbohydrates and good energy producers. Browse - Protein levels 16 to 23% in spring, drops to 8% in mature foliage. Accounts for 10-25% of diet of mule deer in some localities, up to 50% in spring. Cover Excellent for most species	The high wildlife values of scrub oak plus its resistance to chemical control of resprouting makes this type a poor choice for permanent conversion for wildlife purposes. Where other considerations (e.g., fuelbreaks, range, improvements, etc.) dictate, conversion islands of oak should be retained. Oak sprouts are higher in protein than mature leaves so this type is a good choice for browse rejuvenation treatments such as pollarding (top pruning). The association of species in this type make it ideal deer range in most situations.
MOUNTAIN MAHOGANY Cercocarpus betuloides This species is often associated with scrub oak in this type but is seldom as abundant.	Food Seeds - taken by some birds Browse - highly esteemed as forage. Protein levels range from a low of 7% in January to 15% in April and about 9% in fall. Highly palatable; rated excellent for deer (2-5%), good for bighorn.	Leave Mountain mahogany on deer and cattle ranges. In areas where it has reached tree proportions, pollarding to induce sprout growth within reach of browsers may be warranted.
OTHER ASSOCIATED SPECIES: Usually Found At Upper Altitudes of This Type INTERIOR LIVE OAK Quercus wislizenii	Similar to scrub oak described above. Somewhat taller growth form may provide better roosting cover.	Good roost tree.
CHAPARRAL WHITETHORN Ceanothus leucodermis	Food Seeds - in diet of quail, woodrats, ground squirrels. Browse - important to cottontails; fair to good protein supply (11-15%) and preferred by deer; rated good to excellent. Cover Excellent, especially the thorny C. leucodermis.	Leave for browse and cover.
VEATCH SILKTASSEL Garrya veatchii	Food Berries - relished by birds especially robins, waxwings, etc. Browse - fair to good for deer. Protein level is from 5 to 12%. Cover Good to fair for loafing and escape	Adds variety to this type.

EASTWOOD MANZANITA *Arctostaphylos glandulosa*	Least valuable of the common species of this type	Select manzanita patches for wildlife food openings and browseways in this type.

COASTAL SAGEBRUSH TYPE	Location: Generally below 3,000 feet on slopes facing prevailing westerly - in the "fog belt;" Canyon mouths. Climate: Rainfall: 10 to 20 inches Growing season: 8 to 12 months Mean summer max: 68°-90° Mean winter min: 37°-48°	Other Classifications: Coastal Sage Scrub (Munz) Intermediate Valley Climatic Zone Sonoran Life Zone Lower
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: WHITE SAGE *Salvia apiana*	Food Seeds - birds, esp. Lesser goldfinch Flowers - bees, hummingbirds, esp. Costa Browse - low value Cover Loafing cover for small birds and mammals	Consider conversion in dense areas above 15 inches rainfall on suitable soils.
CALIFORNIA SAGEBRUSH *Artemesia californica*	Food Browse - poor Cover Loafing cover for small birds and mammals	Conversion
CALIFORNIA BUCKWHEAT *Eriogonum fasciculatum*	Food Seeds - good, esp. for birds and small mammals; key food for Bell sparrow (10-25% of diet). Flowers - 1-3% of diet of jackrabbits, ground squirrels Cover Little value	Leave patches of buckwheat when planning conversion.
INCIENSO *Encelia farinosa* (Primarily from Plunge Creek east)	Food Seeds - sunflower-like widely used by upland game birds, and esp. American goldfinch, house sparrow and whitecrown sparrow Browse - poor Cover Little value	Leave occasional patches or individual specimens.
OTHER INDICATOR SPECIES: BLACK SAGE *Salvia mellifera*	Food Seeds - goldfinches, other birds Flowers - hummingbirds, esp. Costa Browse - little value	Consider conversion of dense areas to provide interspersion of perennial grasses and forbs.

MONKEY FLOWER *Diplacus longiflorus*	Food *Flowers* - most favored native food of Allen hummingbird - also preferred to Anna hummer Cover Slight value	Leave for value to hummingbirds and scenic beauty.
The Following Usually Occur in This Type as Large Individuals, Widely Spaced: SUGARBUSH *Rhus ovata*	Food *Fruit* - taken by many birds and small mammals, esp. bandtailed pigeon (2-5% of diet), mountain quail (2-5%) Cover Excellent	Leave for cover in conversion projects.
CALIFORNIA SCRUB OAK *Quercus dumosa*	Food *Acorns* - highly valued for many species for mammals and birds. Significant in diet of bandtailed pigeon (10-25% of diet), quail (5-10% fragments), redshafted flicker (5-10%), jays (25-50%), plain titmouse (5-10%), California thrasher (2-5%), raccoon (5-10%), pocketgopher (10-25%), mule deer (10-25% in winter). Acorns are low in protein but high in fats and carbohydrates and good energy producers. Cover Excellent, for most species	Leave for cover in conversion projects.
HOLLYLEAF CHERRY *Prunus ilicifolia*	Food *Fruit and Seeds* - Scrub jay, phainopepla, raccoon, chipmunk and woodrats take the fruit and/or its large seed. *Browse* - preferred by mule deer. Has high (20%) protein levels in spring (April) declining (11%) by fall (Oct) Cover The dense, prickly foliage is excellent cover.	Leave for browse and cover in conversion projects.
MOUNTAIN MAHOGANY *Cercocarpus betuloides*	Food *Seeds* - taken by some birds *Browse* - highly esteemed as forage. Protein levels range from a low of 7% in January to 15% in April and about 9% in fall. Highly palatable; rated excellent for deer (2-5%), good for bighorn.	Leave for cover in conversion projects.

LIVE-OAK CHAPARRAL TYPE	Location: On north-facing slopes from 3,500 to 6,500 feet; south-facing slopes from 4,500 to 7,500. Mostly on the coastal slopes and to a limited extent in the Mojave River drainages. Climate: Rainfall: 22 to 45 inches Growing season: 6 to 9 months Mean summer max: 81°-93° Mean winter min: 26°-40°	Other Classifications: Chaparral (Munz) Mountain Climatic Zone Upper Sonoran and Transition Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: INTERIOR LIVE OAK Quercus wislizenii	Food Acorns - highly valued for many species of mammals and birds. Significant in diet of bandtailed pigeon (10-25% of diet), quail (5-10% fragments), redshafted flicker (5-10%), jays (25-50%), rufous-sided towhee (5-10%), plain titmouse (5-10%), California thrasher (2-5%), raccoon (5-10%), pocketgopher (10-25%), mule deer (10-25% in winter). Acorns are low in protein but high in fats and carbohydrates and good energy producers. Browse - Protein level 16 to 23% in spring, drops to 8% in mature foliage. Accounts for 10-25% of diet of mule deer in some localities, up to 50% in spring. Cover Excellent for most species.	Protected from fire, this chaparral will develop into woodland permitting access to adjoining types; typically scrub oak chaparral on coastal slopes and desert chaparral on interior. Not usually considered good chance for conversion. In fuelbreaks situations, consider thinning and pruning.
CANYON LIVE OAK Quercus chrysolepis Occurs scatteringly throughout type except on drier slopes	Food Acorns - approximately same as above. Browse - low in palatability; crude protein 5 to 11%; rated fair to poor; usually unavailable. Cover Excellent for roosting.	Save for roosting trees.
CALIFORNIA SCRUB OAK Q. dumosa Occurs at lower limits of this type where it merges with other types	Similar to interior live oak described above.	When favoring woodland development, remove this species in favor of Interior or Canyon Live Oak in fuelbreak thinning.
CHAPARRAL WHITETHORN Ceanothus leucodermis MOUNTAIN MAHOGANY Cercocarpus betuloides	These preferred browse species are a valuable supplement to the live oaks in this type.	Retain where possible in development projects.
EASTWOOD MANZANITA Arctostaphylos glandulosa BIGBERRY MANZANITA A. glauca	These species add little to the wildlife values in this type.	Where projects require fuel reduction, select these species.

LIVE-OAK WOODLAND TYPE	Location: Most frequently found on north-facing slopes 3,500 to 6,500 feet but less common than Live Oak Chaparral type. Climate: Rainfall: 22 to 45 inches Growing season: 6 to 9 months Mean summer max: 81°-93° Mean winter min: 26°-30°	Other Classifications: Foothill-Woodland (Munz) Mountain Climatic Zone Upper Sonoran to Transition Life Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: CANYON LIVE OAK Quercus chrysolepis	Food Acorns - highly valued for many species of mammals and birds. Significant in diet of bandtailed pigeon (10-25% of diet), quail (5-10% fragments), redshafted flicker (5-10%), jays (25-50%), rufous-sided Towhee (5-10%), thrasher (2-5%), raccoon (5-10%), pocketgopher (10-25%), mule deer (10-25% in winter). Acorns are low in protein but high in fats and carbohydrates and good energy producers. Browse - Protein levels 16 to 23% in spring, drops to 8% in mature foliage. Accounts for 10-25% of diet of mule deer in some localities, up to 50% in spring. Cover Excellent for roosting.	This type is usually an intermediate stage in the succession to a bigcone douglas-fir Forest Type. There is little habitat management directed toward this type.
BIGCONE DOUGLAS-FIR Pseudotsuga macrocarpa Scattered trees frequently occur among the oaks	Food Seeds - valued by many birds and mammals especially rodents. Foliage - taken sparingly by several forms. Cover Roosting - used by many birds and squirrels. Nesting - important to nuthatches, creepers, woodpecker and other cavity nesters.	Retain a few selected snags for nesting.

BIGCONE DOUGLAS-FIR FOREST TYPE	Location: Usually north-facing slopes. Most extensive in Eastern San Gabriel Mountains. Climate: Rainfall: 22 to 45 inches Growing season: 6 to 9 months Mean Summer max: 81°-93° Mean Winter min: 26°-40°	Other Classifications: Chaparral or (Munz) Yellow Pine Forest (Munz) Mountain Climatic Zone Upper Sonoran Life Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: BIGCONE DOUGLAS-FIR *Pseudotsuga macrocarpa*	Food *Seeds* - valued by many birds and mammals especially rodents. *Foliage* - taken sparingly by several forms Cover *Roosting* - used by many birds and squirrels *Nesting* - important to nuthatces, creepers, woodpecker and other cavity nesters.	Where terrain permits removal to manage for healthy forest, decadent species may be removed to increase vigor of residual stand. Retain a few selected snags for cavity nests or sentinel posts. This type is most valuable for insectivorous birds and for squirrels. It is not extensive and usually is not a habitat which benefits by cultural treatment.
CANYON LIVE OAK *Quercus chrysolepis*	Food *Acorns* - highly valued for many species of mammals and birds. Significant in diet of bandtailed pigeon (10-25% of diet), quail (5-10% fragements), redshafted flicker (5-10%), jays (25-20%), rufous-side towhee (5-10%), plain titmouse (5-10%), California thrasher (2-5%), raccoon (5-10%), pocketgopher (10-25%), mule deer (10-25% in winter). Acorns are low in protein but high in fats and carbohydrates and good energy producers. *Browse* - Protein levels 16 to 23% in spring, drops to 8% in mature foliage. Accounts for 10-25% of diet of mule deer in some localities, up to 50% in spring. Cover Excellent for roosting.	Retain for acorn production minor browse value, cover, etc.

KNOBCONE-PINE FOREST TYPE	Location: Restricted to small areas of poor site in City, Plunge and Keller Creeks. Below 5,000 feet. Climate: Rainfall: 13 to 35 inches Growing season: 8 months Mean Summer max: 82°-94° Mean Winter min: 29°-45°	Other Classifications: Chaparral (Munz) Transition or Mountain Climatic Zone Upper Sonoran Life Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: KNOBCONE PINE Pinus attenuata	Food Seeds - seldom available in this closed cone species Browse - little value Cover Provides good cover for most species	Retain for cover. Site is usually not good enough for conversion.
OTHER ASSOCIATED SPECIES: EASTWOOD MANZANITA Arctostaphylos glandulosa	Food Berries - taken by many birds and mammals, California skunk (2-5%), and jays, mockingbirds, raccoons, ground squirrels, black bear, coyotes, etc. Browse - although taken some by deer, manzanita is a poor source of protein (6% or less) and has few redeeming characteristic for forage; rated poor. Cover Often forms tall, impenetrable thickets - excellent for escape.	Retain for berries and cover in this type except in fuelbreak or browseway locations.
CHAMISE Adenostoma fasciculatum	Food Seeds - important to Lawrence goldfinch (5-10% of diet) Flowers - Woodrats Browse - poor producer of vital protein (4 to 14%) although it provides minimum energy requirements for deer.	Select browseway routes for fuelbreaks through the Chamise when the choice presents itself.
CHAPARRAL WHITETHORN Ceanothus leucodermis	Food Seeds - in diet of quail, woodrats, ground squirrels Browse - important to cottontails; fair to good protein supply (11-15%) and preferred by deer; rated good to excellent. Cover Excellent, especially the thorny C. leucodermis	Retain for browse in this type.
CHAPARRAL-PEA Pickeringia montana	Food Seeds - valued by quail when within their range, ground squirrels, kangaroo rats. Browse - taken by deer, especially after burns; notably high protein levels in April and May (19%) drops to 6 to 8% in winter; rated good to excellent.	Select for browseways to develop sprouts or for pollarding studies.

DESERT CHAPARRAL TYPE	Location: Mojave River drainages, Cajon Pass area, north and east slopes of San Jacinto and Santa Rosa Mountains; 3,800 to 7,500 feet; this type is open grown with numerous sub-shrubs and much exposed soil. Climate: Rainfall: 12 to 25 inches Growing season: 5 to 8 months Mean Summer max: 88°-95° Mean Winter min: 20°-30°	Other Classifications: Pinyon-Juniper Woodland (Munz) Climatic Zone Upper Sonoran Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: **DESERT MAHOGANY** Cercocarpus ledifolius Also found in other types up to 10,900	Food Seeds - taken by some birds Browse - highly esteemed as forage. Protein levels range from a low of 7% in January to 15% in April and about 9% in fall. Highly palatable; rated excellent for deer (2-5%), good for bighorn.	Because of the comparatively low rainfall, this type is open grown with low density. It is very slow to recover after damage by fire, drought or heavy grazing. Major management should be directed toward protection of the valuable forage species where present and available. On depleted areas consider reseeding key species such as Desert Mahogany and flannelbush. Where plants have become unavailable because of height, considerable pollarding projects (top pruning) and moderate grazing with livestock.
CALIFORNIA SCRUB OAK Quercus dumosa **CANYON LIVE OAK** Q. chrysolepis	Food Acorns - highly valued for many species of mammals and birds. Significant in diet of bandtailed pigeon (10-25% of diet), quail (5-10% fragments), redshafted flicker (5-10%), jays (25-50%), rufous-sided towhee (5-10%), plain titmouse (5-10%), California thrasher (2-5%), raccoon (5-10%), pocketgopher (10-25%), mule deer (10-25% in winter). Acorns are low in protein but high in fats and carbohydrates and good energy producers. Browse - Protein levels 16 to 23% in spring, drops to 8% in fall with mature foliage. Accounts for 10-25% of diet of mule deer in some localities, up to 50% in spring. Cover Excellent for most species.	See above.
DESERT CEANOTHUS Ceanothus greggii	Food Seeds - used by quail, woodrats, ground squirrels. Browse - used by jackrabbits, deer, but less valuable than other Ceanothus; rated fair Cover Fair	See above.
FLANNEL BUSH Fremontia californica	Food Seeds - rodents Browse - taken with apparent relish by all classes of hoofed browsers; rated excellent for deer.	See above.
VEATCH SILKTASSEL Garrya veatchii	Food Berries - relished by birds especially robins, waxwings, etc. Browse - fair to good for deer. Protein level is from 5 to 12%. Cover Good to fair for loafing and escape.	See above

PINYON-JUNIPER WOODLAND TYPE	Location: Principally in Deep Creek, in the vicinity of Big Bear Lake, on the north slopes of Santa Rosa Peak and Martinez Mountain; also occurs in Cajon Creek; at elevations between 3,000 to 9,000 feet. Climate: Rainfall: 10 to 30 inches Growing season: 5 to 8 months Mean Summer max: 88°-95° Mean Winter min: 20°-30°	Other Classifications: Pinyon-Juniper Woodland (Munz) High Desert Climatic Zone Upper Sonoran Life Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: SINGLELEAF PINYON Pinus monophylla FOURLEAF PINYON Pinus quadrifolia This species replaces the singleleaf in parts of the San Jacinto and Santa Rosa Mountains.	Food Seeds - all open cone pine seeds are heavily used by wildlife. Because of its size the pinyon nut is especially prized. It is vital in the diet of the whiteheaded woodpecker (71% of diet) and pine nuts comprise 75% of the diet of Clark's nutcracker. Other users include mourning dove (2-5%), bandtailed pigeon (10-25%), mountain chickadee (2-5%), rosy finch (5-10%), evening grosbeak (10-25%), pinyon jay (25-50%), pygmy and redbreasted nuthatches (25-50%), whitebreasted nuthatches (5-10%), and many other birds, black bear (5-10%), gray squirrel (25-50%), and others. Browse - taken in varying amounts by deer and bighorn. Cover Excellent, main nesting cover of mourning dove on desert slopes.	While pinyon and juniper are important to many species, the type can generally be made more productive by converting some of the acreage to perennial grasses and by releasing the associated desert chaparral browse species. Islands of pinyon-juniper should be retained for their intrinsic values as well as cover.
CALIFORNIA JUNIPER Juniperus californica Occurs at lower altitudes where rainfall is very low. WESTERN JUNIPER Juniperus occidentalis Occurs at highest portions of type as at Big Bear Lake to Onyx Summit (not in San Jacinto)	Food Berries - taken by many birds, notably bluebird (2-5%), purple finch (5-10%), evening grosbeak (10-25%), pinyon jay (5-10%), mockingbird (2-5%), robin (2-5%), townsend solitaire (5-10%), Cedar waxwing (25-50%); many rodents and in small amounts by coyote, ringtailed cut and others. Browse - taken in some parts rather heavily but not noticeably on the San Bernardino National Forest. Cover Excellent; especially some of the bushy, open grown specimens.	See above.
OTHER ASSOCIATED SPECIES: Desert chaparral type is generally associated with the P-J Woodland type except in the Big Bear area where the Great Basin sagebrush type is more generally associated.	See descriptions under the other types.	Retain and improve by releasing browse species from pinyon-juniper competition. Favor native perennial grasses by release-spraying sagebrush and rabbitbrush.

GREAT BASIN SAGEBRUSH TYPE	Location: Most commonly on gentle slopes and valley floors on desert slopes; 3,000 to 7,000 feet. Climate: Rainfall: 10 to 30 inches Growing season: 5 to 8 months Mean Summer max: 88°-95° Mean Winter min: 20°-30°	Other Classifications: Sagebrush Scrub (Munz) High Desert Climatic Zone Upper Sonoran Life Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: BASIN (BIG) SAGEBRUSH *Artemesia tridentata* BLACK SAGEBRUSH *Artemesia arbuscula nova*	Food *Seeds* - used by a few species of birds and mammals. *Browse* - a staple for wintering deer on desert slopes, but must be taken with other species to be digestible. Black sagebrush may be more palatable than Basin. Cover Important to some species of birds in foraging.	Sagebrush on gentle slopes and valley floors is often evidence of past heavy grazing on native perennials and subsequent encroachment by the sagebrush. When residual grasses constitute 6 to 8% of ground cover, consider release spraying sagebrush with 2 lbs. 2, 4-D per acre. If perennials are depleted, spray should be followed by reseeding with wheatgrasses. There is sufficient sagebrush in other areas to provide any needs not now recognized.
OTHER ASSOCIATED SPECIES: RABBITBRUSH *Chrysothamnus spp.*	Food Slightly used by some birds and by rabbits. Poor browse for deer.	Should be included for spraying to release more valuable grasses.
BUCKWHEATS *Eriogonum spp.* SAGES *Salvia spp.* BLACKBRUSH *Coleogyne ramossissima*	Generally low value in this type except as cover for birds which use grasses and forbs in this type for food.	Same as above.

TIMBERLAND CHAPARRAL TYPE	Location: Throughout the higher mountains; best developed in eastern San Bernardino Mountains, 5,000 to 11,000 feet. Climate: Rainfall: 30 to 45 inches Growing season: 2 to 7 months Mean Summer max: 65°-80° Mean Winter min: ? -34°	Other Classifications: Yellow Pine Forest (Munz) and Subalpine Forest Mountain Climatic Zone Transition and Boreal Life Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES MOUNTAIN WHITETHORN Ceanothus cordulatus	Food Seeds - mountain quail, chipmunks take some. Browse - fair to good protein levels (6 to 15%); preferred by deer (33% of diet in some localities); rated good to excellent. Cover Excellent for escape, nesting cover.	This type provides good wildlife feed and cover at the higher elevations where it is open grown with only about 50% cover density. At the lower (5-6,000') elevations it forms solid brushfields which could be improved by browse-ways, openings and accessways. In the denser stands it is usable mainly by nesting songbirds.
PARRY MANZANITA Arctostaphylos parryana var. pinetorum	Food Berries - taken by many birds and mammals, especially fox sparrow (10-25% of diet), black bears, etc. Browse - rated poor. Cover Excellent; provides nesting cover for fox sparrow, green-tailed towhee and others.	See above.
BUSH CHINQUAPIN Castanopsis sempervirens	Food Nuts - taken by chipmunks (2-5%) in small amounts by other rodents and birds. Browse - poor to useless. Cover Fair	See above.
DEER BRUSH Ceanothus integerrimus	Food Seeds - mountain quail, chipmunks and rodents take some. Browse - one of the most valued summer browse feeds in California; well-balanced amounts of crude protein, fat, mineral matter and nitrogen-free extract; protein levels have been measured as high as 27% in spring; a higher nutritive value than most grasses. Cover Good	Deerbrush should be encouraged where found. When clearing for plantations, leave as much as possible. It will divert deer from the seedlings. After 10 to 15 years of age, deerbrush may be out-of-reach or decadent. Pollarding may induce sprouting and increased vigor.

PINE FOREST TYPE	Location: Rather extensive in the San Bernardino and San Jacinto Mountains between 5,000 and 8,000 feet; also in San Gabrieis and Santa Rosa to limited extent. Climate: Rainfall: 25 to 50 inches Growing season: 4 to 7 months Mean Summer max: 80°-93° Mean Winter min: 22°-34°	Other Classifications: Yellow Pine Forest (Munz) Mountain Climatic Zone Transition Life Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: COULTER PINE Pinus coulteri Generally at lower levels; common in headwaters Deep Creek and Mojave River, Western slopes of San Jacinto. PONDEROSA PINE Pinus ponderosa Mostly below 6,000 feet. JEFFREY PINE Pinus jeffreyi Mostly above 6,000 feet.	Food Pines rank near the very top in importance to wildlife. They are included in the diet of more species than any other genus save oak. Seeds - notably valuable to Clark nutcracker (74% of diet), red crossbill (66%), pygmy nuthatch (25-50%), redbreasted nuthatch (25-50%), chipmunks (25-50%), bandtailed pigeon (10-25%), evening grosbeak (10-25%), hermit warbler (10-25%), rosy finch (5-10%), pinesiskin (5-10%), Lewis woodpecker (5-10%), antelope ground squirrel (5-10%), whitefooted mouse (5-10%) and many others to a lesser degree. Seeds, bark, foliage - taken by beaver (5-10%), gray squirrel (25-50%), and locally by deer in varying amounts. Cover Vital for nesting for several species such as nuthatches, brown creeper, woodpeckers, eagles, bandtailed pigeons, flying and gray squirrels and many others.	Manage in accordance with Timber Management Plan for Southern California Forests and San Bernardino Working Circle to promote a healthy vigorous forest for its recreation and watershed values. When seeding skidtrails and landings, consider wildlife enhancement in seedmix. Judiciously select snags to be retained for cavity nesters and for nests and sentinel posts for hawks, owls, eagles.
CALIFORNIA BLACK OAK Quercus kelloggii	Food Acorns - probably at the top of the wildlife food list nation-wide. Their greatest value is in the critical winter season when other foods are scarce. In this area they are of particular value to bandtailed pigeon (25-50% of diet), scrub jay (25-50%) Steller jay (25-50%), gray squirrel (25-50%), whitebreasted nuthatch (10-25%), varied thrush (10-25%), Lewis woodpecker (10-25%), acorn woodpecker (10-25%), flying squirrel (10-25%), beechey ground squirrel (10-25%), mule deer (10-25%) and at least ten other species. Browse - black oak sprouts, leafage and twigs are used extensively when within reach by deer, rated good to excellent. Cover Often used as den trees and nesting by birds and squirrels.	Black oak should be retained as a valuable component of the recreation forest for its beauty, variety and contrast, its wildlife values and watershed values. Removal of decadent trees is justified to reduce overstocking and promote more vigorous, healthy young growth. Care should be taken to retain den trees.

PONDEROSA PINE- WHITE FIR FOREST TYPE	Location: On gentle to moderate slopes with deep soils at altitudes of 5,000 to 8,000 feet. Occurs in small stands throughout the coniferous forests but is most extensive in headwaters of Santa Ana River and Deep Creek and in Black Mountain Scenic Area. Climate: Rainfall: 25 to 50 inches Growing season: 4 to 6 months Mean Summer max: 80°-93° Mean Winter min: 22°-34°	Other Classifications: Yellow Pine Forest (Munz) Mountain Climatic Zone Transition and Boreal Life Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: PONDEROSA PINE *Pinus ponderosa* or JEFFREY PINE *Pinus jeffreyi*	Food Pine rank near the very top in importance to wildlife. They are included in the diet of more species than any other genus save oak. Seeds - notably valuable to Clark nutcracker (74% of diet), red crossbill (66%), pygmy nuthatch (25-50%), redbreasted nuthatch (25-50%), chipmunks (25-50%), bandtailed pigeon (10-25%), evening grosbeak (10-25%), hermit warbler (10-25%), rosy finch (5-10%), pinesiskin (5-10%), Lewis woodpecker (5-10%), antelope ground squirrel (5-10%), white-footed mouse (5-10%) and many others to a lesser degree. Seeds, bark, foliage - taken by beaver (5-10%), gray squirrel (25-50%), and locally by deer in varying amounts. Cover Vital for nesting for several species such as nuthatches, brown creeper, woodpeckers, eagles, bandtailed pigeons, flying and gray squirrels and many others.	Manage in accordance with Timber Management Plan for Southern California Forests and San Bernardino Working Circle to promote a healthy vigorous forest for its recreation and watershed values. When seeding skidtrails and landings, consider wildlife enhancement in seed mix. Judiciously select snags to be retained for cavity nesters and for nests and sentinel posts for hawks, owls, eagles.
WHITE FIR *Abies concolor*	Food Seeds - taken by many birds and squirrels including Clark nutcracker (2-5%), chipmunks (2-5%), red crossbill, pygmy nuthatch, whitefooted mouses and others. Twigs and needles - palatability and preference appears to vary greatly between individual plants. Young fir trees are not infrequently browsed heavily by deer.	See above.
OTHER ASSOCIATED SPECIES: SUGAR PINE *Pinus lambertiana* INCENSE CEDAR *Libocedrus decurrens*	See pines above. Sugar pine is especially valuable for its large seeds and as a perch because of its height. Food Incense Cedar is only of minor value as wildlife food. Cover The dense protective shelter of cedar is especially valuable in winter.	See above.
CALIFORNIA BLACK OAK *Quercus kelloggii*	Food Acorns - probably at the tope of the wildlife food list nation-wide. Their greatest value is in the critical winter season when other foods are scare. In this area they are of particular value to bandtailed pigeon (25-50%) of diet, scrub jay (25-50%), steller jay (25-50%), gray squirrel (25-50%), whitebreasted nuthatch (10-25%), varied thrush (10-25%), Lewis woodpecker (10-25%), acorn woodpecker (10-25%), flying squirrel (10-25%), beachey ground squirrel (10-25%), mule deer (10-25%) and at least ten other species. Browse - black oak sprouts, leafage and twigs are used extensively when within reach by deer, rated good to excellent. Cared leaves are used by deer when softened by rains. Cover Often used as den trees and nesting by birds and squirrels.	Black oak should be retained as a valuable component of the recreation forest for its beauty, variety and contrast, its wildlife values and watershed values. Removal of decadent trees is justified to reduce over-stocking and promote more vigorous, healthy young growth. Care should be taken to retain den trees.

SUGAR PINE- WHITE FIR FOREST TYPE	Location: Widespread in San Gabriels, in Mill Creek and Santa Ana River in San Bernardinos and to limited extent in San Jacintos mostly on south facing steep slopes with active creep; altitudes 5,000 to 8,000 feet. Climate: Rainfall: 25 to 50 inches Growing season: 4 to 6 months Mean Summer max: 80°-93° Mean Winter min: 22°-34°	Other Classifications: Yellow Pine Forest (Munz) Mountain Climatic Zone Transition and Boreal Life Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES SUGAR PINE Pinus lambertiana JEFFREY PINE Pinus jeffreyi	Food Pines rank near the very top in importance to wildlife. They are included in the diet of more species than any other genus save oak. Seeds - notably valuable to Clark nutcracker (74% of diet), red crossbill (66%), pygmy nuthatch (25-50%), redbreasted nuthatch (25-50%), chipmunks (25-50%), bandtailed pigeon (10-25%), evening grosbeak (10-25%), hermit warbler (10-25%), rosy finch (5-10%), pinesiskin (5-10%), Lewis woodpecker (5-10%), antelope ground squirrel (5-10%), white-footed mouse (5-10%), and many others to a lesser degree. Seeds, bark, foliage - taken by beaver (5-10%), gray squirrel (25-50%), and locally by deer in varying amounts. Cover Vital for nesting for several species such as nuthatches, brown creeper, woodpeckers, eagles, bandtailed pigeons, flying and gray squirrels and many others.	Management in accordance with Timber Management Plan for Southern California Forests and San Bernardino Working Circle to promote a healthy vigorous forest for its recreation and watershed values where slopes permit. When seeding skidtrails and landings, consider wildlife enhancement in seed mix. Judiciously select snags to be reatined for cavity nesters and for nests and sentinel posts for hawks, owls, eagles.
WHITE FIR Abies concolor	Food Seeds - taken by many birds and squirrels including Clark nutcracker (2-5%), chipmunks (2-5%), red crossbill, pygmy nuthatch, whitefoot mice and others. Twigs and needles - palatable and preference appears to vary greatly between individual plants. Young fir trees are not infrequently browsed heavily by deer.	
ASSOCIATED SPECIES: CANYON LIVE OAK Quercus chrysolepis	Food Acorns - highly valued for many species of mammals and birds. Significant in diet of bandtailed pigeon (10-25% of diet), quail (5-10% fragments), redshafted flicker (5-10%), jays (25-50%), rufous-sided towhee (5-10%), plain titmouse (5-10%), California thrasher (2-5%), raccoon (5-10%), pocketgopher (10-25%), mule deer (10-25% in winter). Acorns are low in protein but high in fats and carbohydrates and good energy producers. Browse - Protein levels 16 to 23% in spring, drops to 8% in mature foliage. Accounts for 10-25% of diet of mule deer in some localities, up to 50% in spring. Cover Excellent for roosting.	Leave for mast, cover and variety.
Timberland chaparral species are often associated with this type. There is little herbaceous understory.		

GRASSLAND TYPE	Location: On alluvial soils in the Forest Zone. Nowhere extensive. Both dry grasslands and wet grasslands occur. Introduced grasslands now total over 5,000 acres through type conversion efforts Climate: Rainfall: 25 to 50 inches Growing season: 4 to 7 months Mean Summer max: 80°-93° Mean Winter min: 22°-34°	Other Classifications: Yellow Pine Forest (Munz) Mountain Climatic Zone Transition Life Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: DRY GRASSLANDS These areas contain many species of annual grasses and forbs. Bromus - Species are typical. Bunchgrasses and perennial forbs are also found.	Grass seeds are valuable to birds and small mammals. Their leaves and stems are used by rabbits, deer and other herbivores, and in addition the plants provide protective cover to many small and medium-sized animals. Individual grasses and forbs of specific value are listed in the R5 Range Analysis Field Guide.	Maintain and where possible enhance by addition of perennials, legumes, etc.
WET GRASSLANDS Predominantly sedges, Carex sp and Rushes, Juncus sp.	Achens of sedge are eaten by many species of wildlife. Rush is less valuable.	Maintain wet meadow types and enhance by addition of legumes.

BLACK-OAK WOODLAND TYPE	Location: Common from 5,000 to 7,000 feet usually on flat or rolling sites with deep soil Climate: Rainfall: 25 to 50 inches Growing season: 4 to 7 months Mean Summer max: 80°-91° Mean Winter min: 22°-34°	Other Classifications: Yellow Pine Forest (Munz) Mountain Climatic Zone Transition Life Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: CALIFORNIA BLACK OAK *Quercus kelloggii*	Food Acorns - probably at the top of the wildlife food list nation-wide. Their greatest value is in the critical winter season when other foods are scarce. In this area they are of particular value to bandtailed pigeon (25-50% of diet), scrub jay (25-50%), gray squirrel (25-50%), Steller jay (25-50%), whitebreasted nuthatch (10-25%), varied thrush (10-25%), Lewis woodpecker (10-25%), acorn woodpecker (10-25%), flying squirrel (10-25%), mule deer (10-25%), and at least ten other species. Browse - black oak sprouts, leafage and twigs are used extensively when within reach by deer-rated good to excellent. Cover Often used as den trees and nesting by birds and squirrels.	A large part of the black oak woodland type was formed as a result of early day logging of the conifers. The mature conifers were removed, and subsequent burning destroyed young trees. The California black oak, which sprouts vigorously from the burned stump, then became the dominant species wherever it was common in the original forest. In recent years under more intensive fire protection, ponderosa pine is becoming more abundant in the woodland stands. Manage to increase variety of species in stand.
CANYON LIVE OAK *Quercus chrysolepis*	Food Acorns - as above Browse - low in palatability; crude protein 5 to 11%; rated fair to poor; usually unavailable. Cover Excellent for roosting.	Save for roosting trees.
PONDEROSA PINE *Pinus ponderosa*	Food Pines rank near the very top in importance to wildlife. They are included in the diet of more species than any other genus save oak. Seeds - notably valuable to Clark nutcracker (74% of diet), red crossbill (66%), pygmy nuthatch (25-50%), red-breasted nuthatch (25-50%), chipmunks (25-50%), bandtailed pigeon (10-25%), evening grosbeak (10-25%), hermit warbler (10-25%), rosy finch (5-10%), pinesiskin (5-10%), Lewis woodpecker (5-10%), antelope ground squirrel (5-10%), white-footed mouse (5-10%) and many others to a lesser degree. Seeds, bark, foliage - taken by beaver (5-10%), gray Squirrel (25-50%), and locally by deer in varying amounts. Cover Vital for nesting for several species such as nuthatches, brown creeper, woodpeckers, eagles, bandtailed pigeons, flying and gray squirrels and many others.	Maintain to increase variety.
BIGCONE DOUGLAS-FIR *Pseudotsuga macrocarpa*	Food Seeds - valued by many birds and mammals especially rodents. Foliage - taken sparingly by several forms. Cover Roosting - used by many birds and squirrels. Nesting - important to nuthatches, creepers, woodpeckers and other cavity nesters.	Maintain to increase variety.
DEERBRUSH *Ceanothus integerrimus*	Food Seeds - mountain quail, chipmunks and rodents take some. Browse - one of the most valued summer browse feeds in California; well-balanced amounts of crude protein, fat, mineral matter and nitrogen-free extract; protein levels have been measured as high as 27%, a higher nutritive value than most grasses. Cover Good	Deer brush sould be encouraged where found. When clearing for plantations, leave as much as possible. It will divert deer for seedlings. After 10 to 15 years of age, deer brush may be out-of-reach or decadent. Pollarding may induce sprouting and increased vigor.

ALPINE FOREST TYPE	Location: Occurs above 8,000 feet on the high mountains of the San Bernardino, San Gabriel, San Jacinto and Santa Rosa ranges. Climate: Rainfall (Snow): 25-50 inches Growing Season: 7 to 14 weeks Mean Summer max: 65° Mean Winter min: 5°	Other Classifications: Lodgepole Forest and Subalpine Forest (Munz) Mountain Climatic Zone Boreal Life Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: LODGEPOLE PINE Pinus contorta	Food Pines rank near the very top in importance to wildlife. They are included in the diet of more species than any other genus save oak. Seeds - notably valuable to Clark nutcracker (74% of diet), red crossbill (66%), pygmy nuthatch (25-50%), red-breasted nuthatch (25-50%), chipmunks (25-50%), bandtailed pigeon (10-25%), evening grosbeak (10-25%), hermit warbler (10-25%), rosy finch (5-10%), pinesiskin (5-10%), Lewis woodpecker (5-10%), antelope ground squirrel (5-10%), white-footed mouse (5-10%) and many others to a lesser degree. Seeds, bark, foliage - taken by beaver (5-10%), gray squirrel (25-50%), and locally by deer in varying amounts. Cover Vital for nesting for several species such as nuthatches, brown creeper, woodpeckers, eagles, bandtailed pigeons, flying and gray squirrels and many others.	Because cover is scarce, existing vegetation is encouraged.
LIMBER PINE Pinus flexilis	Food Pines rank near the very top in importance to wildlife. They are included in the diet of more species than any other genus save oak. Seeds - notably valuable to Clark nutcracker (74% of diet), red crossbill (66%), pygmy nuthatch (25-50%), red-breasted nuthatch (25-50%), chipmunks (25-50%), bandtailed pigeon (10-25%), evening grosbeak (10-25%), hermit warbler (10-25%), rosy finch (5-10%), pinesiskin (5-10%), Lewis woodpecker (5-10%), antelope ground squirrel (5-10%), white-footed mouse (5-10%), and many others to a lesser degree. Seeds, bark, foliage - taken by beaver (5-10%), gray squirrel (25-50%), and locally by deer in varying amounts. Cover Stunted, shrublike (Krummholz) pines provide excellent cover. The more erect specimens are used by cavity-nesters.	In some areas grass would be a valuable addition to the flora. Consider small plots in bighorn range.
OTHER SPECIES: Timberland chaparral species occur as isolated individuals throughout this type.	See Timberland Chaparral Type.	

BARREN AREAS	Location: Principally occur on the highest peaks usually above 7,000. Above 10,000 are widespread and occupy moderate as well as precipitous slopes. Rocky cliffs are a type of barren area important to several species of wildlife. Climate:	Other Classifications: Alpine Fell-field (Munz) Mountain Climatic Zone Boreal Life Zone
SPECIES	WILDLIFE VALUES	MANAGEMENT
By definition, barren areas have less than 5% of the surface covered by vegetation. Several palatable forbs and a few grasses are found in the higher areas and are reported in San Gorgonio Bighorn Habitat Management Plan and San Gabriel Bighorn Habitat Management Plan.	Cover Rocky cliffs and precipitous terrain in barren areas afford excellent "cover" for species nimble enough to negotiate the area. They afford vantage points to observe the approach of enemies. The bighorn is seldom found far from this type. Some species of birds will nest nowhere else.	With bighorn, food is often limiting adjacent to the barren cover areas. Grass should be planted where soil and slope afford an opportunity for success.

RIPARIAN WOODLAND TYPE	Location: In narrow belts along permanently flowing streams in all zones. Also in other canyons where groundwater is near the surface; at springs and seeps. Climate: In all conditions where abundant moisture is present.	Other Classifications: All zones and types
SPECIES	WILDLIFE VALUES	MANAGEMENT
DOMINANT SPECIES: Below 7,000 feet: WHITE ALDER Alnus rhombifolia	Food Seeds - taken by a few birds, notably goldfinch (2-5% of diet) and pinesiskin (2-5%). Browse - taken fairly often, probably for moisture and roughage; low value - rated fair to useless for deer. Bark - taken in limited amounts by beaver. Cover Dense stands provide effective escape cover and shelter.	Generally maintain cover along flowing streams for shade and water temperature control and cover. In very dense situations, thinning for water-yield may be justified but wildlife values must be fully considered.
FREMONT COTTONWOOD Polulus fremontii BLACK COTTONWOOD Populus trichocarpa	Food Buds, catkins, seeds - taken by quail (locally up to 10%), other birds. Bark - highly preferred by beaver (up to 50% of diet in some locales), also used by cottontails, squirrels and meadow mouse. Browse - used frequently by deer but rated fair to poor as feed. Cover Fair, commonly used by cavity nesting birds.	
CALIFORNIA SYCAMORE Platanus racemosa	Food Sycamore is generally of little value; the pendant seed balls are utilized by only a few species, the purple finch being the only bird using the seed in measurable amounts (2-5%). Beaver may take a bite in passing. Cover May be valuable as a perch for insectivorous birds and for nesting.	Leave specimen trees for their beauty.
OTHER SPECIES: The following occur only in the chaparral zones of the coastal slopes. COAST LIVE OAK Quercus agrifolia	Food Acorns - highly valued for many species of mammals and birds. Significant in diet of bandtailed pigeon (10-25% of diet), quail (5-10% fragments), redshafted flicker (5-10%), jays (25-50%), rufous-sided towhee (5-10%), plain titmouse (5-10%), California thrasher (2-5%), raccoon (5-10%), pocketgopher (10-25%), mule deer (10-25% in winter). Acorns are low in protein but high in fats and carbohydrates and good energy producers. Browse - Protein levels 16 to 23% in spring, drops to 8% in mature foliage. Accounts for 10-25% of diet of mule deer in some localities, up to 50% in spring. Cover Excellent for most species.	Leave for food value.
BIGLEAF MAPLE Acer macrophyllum	Food Seeds, buds and flowers - taken by evening grosbeak, nuthatches, purple finch, sapsuckers (sap), flying squirrel, gray squirrel, chipmunk, white-footed mouse, woodrat. Browse and bark - Used by beaver and deer. Leafage is usually out of reach of deer but sprouts are cropped with relish; rated fair to poor. Cover Fair to good; birds use the seed stalks in nest buildings.	Leave for food and cover.

CALIFORNIA LAUREL (BAY) Umbellularia californica	Food Berries - little used Browse - seldom used especially when mature. However sprouts, which occur after a fire or cutting, are often heavily browsed by deer. Some individual plants may be killed by close cropping. After reaching maturity, their palatability apparently decreases markedly; rated good to fair for deer. Cover Good	Leave for cover.
DOMINANT SPECIES: Above 7,000 feet The principal riparian dominants at higher elevations are the several species of:		
WILLOW Salix lasiandra S. l. var. Abramsii S. caudata var. Bryantiana S. melanopsis S. m. var. Bolanderiana S. lutea var. Watsonii S. lemmonii S. Scouleriana	Food Buds, twigs, foliage - important to many birds and mammals including Pine grosbeak (5-10% of diet), cottontail rabbit, meadow mouse; perhaps more important, willows are resting places and cover for many forms of terrestrial insects and thus attract many species of insectivorous birds such as warblers, vireos, chickadees, tit-mice and others. Bark - heavily used by the beaver. It is their principal food species on this forest, wherever it is present in their range. Browse - Willow browse is of relatively good nutritional balance, crude protein levels vary from 7 to 18% with bare twigs of winter dropping to 4-5%. Rating yearlong: fair. Cover Excellent in summer.	Willows normally should be left for food and cover. However in some instances unbroken, dense decadent stands develop where thinning, topping and opening-up would benefit wildlife as well as other values.

OTHER IMPORTANT WILDLIFE PLANTS	Location: The plants on this list are not confined to a single vegetation type but are relatively common and have importance to wildlife. This list is not intended to be all-inclusive. Climate:	Other Classifications:
SPECIES	WILDLIFE VALUES	MANAGEMENT
CALIFORNIA COFFEEBERRY Rhamnus californica HOLLYLEAF REDBERRY Rhamnus crocea var. ilicifolia	Food Berries - provides 5-10% of diet of Mockingbird, Phainopepla, Swainson thrush; also used by bandtailed pigeon, California thrasher, Sapsucker, raccoon and robin, hermit thrush, varied thrush, bear, ringtailed cat, beechey ground squirrel and woodrat. Browse - taken by deer and bighorn; crude protein ranges from 7.5 to 19%; browse rated good to poor for deer--coffeeberry is preferred over redberry. Cover Fair to good.	The buckthorns seldom form dense stands. Their presence adds variety of food and cover type and usually are good candidates for "leave" shrubs in brush conversions.
POISON-OAK Rhus diversiloba SQUAWBUSH Rhus trilobata	Food Berries - Sumac berries are taken by a large number of birds; they are significant in the diet of the wrentit (10-25%) and the pocket mouse (10-25%) and important (5-10%) for red-shafted flicker, sapsuckers, California thrasher, hermit and Swainson thrushes and downy and nuttall woodpecker. Browse - poison-oak rates higher than grass in crude protein content. In its early growth stage it has been found as high as 35%; it drops to 8% in the mature leaf. Squawbush is less palatable. Poison-oak rates good for deer; squawbush fair to poor. Cover Fair to excellent.	The sumacs occasionally occur in very dense patches which afford excellent cover. However poison oak's anti-social qualities make it hard to recommend for a "leave" plant in areas of public use. Nevertheless, it has redeeming features for wildlife.
OTHER SPECIES:		
GOOSEBERRY AND CURRANT Ribes sp.	Food Berries - taken by many birds, small mammals, coyotes. Browse - rated fair to poor for deer although taken fairly heavily after frosts have turned the leaves. Cover Spiny species excellent; other good to fair.	Useful for variety - especially in Timber Chaparral type.
ELDERBERRY Sambucus caerulea	Food Berries - especially important source of summer food for many kinds of songbirds. Robins and others eagerly consume the berries even before they ripen. Elderberries are of high value to phainopepla (up to 50% of diet), blackheaded grosbeak (5-10%), Steller jay (5-10%), Swainson thrush (5-10%), many others. Browse - taken eagerly by deer in late summer and fall especially after frosts have blackened the leaves. Rated good to poor. Cover Fair	Encourage for its high value for songbirds.

SERVICEBERRY Amelanchier alnifolia	Food Berries - sought by thrushes and many songbirds during early summer. Squirrels, chipmunks and even bears relish the fruit; frequented by green-tailed towhee north of Onyx Summit. Browse - sought by most grazing animals; protein levels above 10% through the summer, lower in winter. Rated good to fair for deer. Cover Fair	Serviceberry is a sprouter and should respond well to pollarding.
FOURWING SALTBUSH Atriplex canescens	Food Seeds - valuable for quail, kangaroo rats, pocket mice, horned lark. Browse - highly palatable and nutritious. Good deer winter food; taken heavily by jackrabbits. Rated good to fair for deer. Cover Good to excellent.	Highly adaptable to different sites. One of the best species for browse plantings, although may need protection from rodents and rabbits when seedling.

The Impact of Photochemical Air Pollution on the Mixed-Conifer Forest Ecosystem--Arthropods

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The Impact of Photochemical Air Pollution on the Mixed-Conifer Forest Ecosystem--Arthropods

The mixed conifer forest of the Westside of the Sierra Nevada Mountains has served man as a renewable source of timber, water, forage and wildlife. Demand for these resources and the development of new uses, i.e., for homesites and many forms of recreation, is increasing as populations and their mobility increase. Furthermore, timber harvest is predicted to decline 20% by the end of the century (Oswald, 1970).

Man's activities, such as logging, both fire prevention and fire initiation, road and dam construction, clearing for transmission lines, home building, inundation and stream diversions, surface mining, application of pesticides and photochemical air pollution, have seriously disrupted these forest ecosystems. Extreme site deterioration has often resulted from mining, burning and logging. In these instances, bare soil of the lower horizons is all that remains where trees once stood. However, less extreme site deterioration is more common, resulting in the replacement of forests with brush species.

Animals have played an influential and selective role in determining the succession of vegetation following these disruptions. They assist in the incorporation of organic matter into the soil and in the release to the soil of minerals tied up in plant residues. As primary and secondary consumers, pollinators, and disease vectors they assist one species to displace another. Soil components, such as arthropods, pathogens, moisture, structure and chemistry, in turn influence the capacities of plants to tolerate animal damage. Also, during vegetation succession there is a concomitant succession of arthropods in both existing and newly created aquatic habitats.

Our approach will be to focus on the web of relations among arthropods exposed to high, moderate and low levels of photochemical air pollutants in an attempt to determine how these pollutants nfluence the capacities of plants to tolerate animal damage. Also, during vegetation succession there is a concomitant succession of arthropods in both existing and newly created aquatic habitats.

Our approach will be to focus on the web of relations among arthropods exposed to high, moderate and low levels of photochemical air pollutants in an attempt to determine how these pollutants influence populations of arthropods that are 1) known or suspected to play crucial roles in changing age structure and species composition of vegetation; 2) occupy aquatic habitats, and 3) inhabit the soil.

Because of the enormous number and diversity of this group of organisms their study in relation to air pollution is virtually unlimited. Therefore, we propose that efforts be directed to at least the above major habitats in the mixed-conifer ecosystem. The literature review is therefore limited to only a few key references for each study viewed as most promising in revealing the various impacts of photochemical pollutants on this ecosystem. Of course, these studies must be integrated with the other components in order to qualify as ecosystem research.

See page C-26 for a first approximation of the photochemical air pollution and consumer subsystem.

I. Terrestrial Habitats

A. The Role of the Western Pine Beetle in the Succession of the Mixed-Conifer Ecosystem Exposed to Photochemical Air Pollutants.

The western pine beetle (Dendroctonus brevicomis) plays a significant role in the succession of coniferous ecosystems in western North America. In the interior ponderosa pine of the forests in the north plateau subregion, mature and overmature stands are killed by this bark beetle in patterns that favor both the younger and thriftier age-groups of ponderosa pine (Keen, 1950). The role of this primary tree killer in westside mixed-conifer forests is not so clearly understood. However, during dry climate cycles up to 90% of some stands are killed (Keen, 1950).

Man's activities have created conditions which favor this insect as an important agent in changing the course of plant succession. Trees injured directly through logging and construction activity and indirectly through changes in drainage patterns become more susceptible to infestation (Miller and Keen, 1960). Thus, attraction centers are created, which increases the risk of attack on nearby uninjured trees (Hall and Pierce, 1965). Certain root pathogens (Fomes annosus and Verticicladiella wagenerii) predispose ponderosa pine to attack by this bark beetle (Cobb et al., 1971). The incidence of these root diseases in second-growth stands has probably been favored by logging activity. Ponderosa pines exhibiting advanced symptoms of photochemical air pollution injury are killed by D. brevicomis and D. ponderosae at a much greater rate than are healthy trees (Stark et al., 1968). (See Appendix--"History of Tree Losses in the Vicinity of Lake Arrowhead, San Bernardino County, California 1922-71"). Even-aged stands, resulting from logging activity at the turn of the century as well as those stands created by fire, are particularly susceptible to the western pine beetle (Miller and Keen, 1960). A light selection cut has been found to reduce mortality from D. brevicomis in eastside (Wickman and Eaton, 1962) and in Southern California (Hall and Pierce, 1965) forests.

Techniques are now available to estimate the total population of the western pine beetle and 80 species of parasites, predators and other associated insects (Dahlsten, 1970; Otvos, 1970; Demars, et al., 1970). This includes tree sampling methods (DeMars, 1970; Berryman, 1970) which provide estimates of population variability between trees, and aerial photographic techniques (Caylor and Thorley, 1970) which provide estimates of the total number of infested trees over large areas. Using life tables (DeMars et al., 1970) it should be possible to detect differences in abundance and structure of populations in areas variously exposed to pollutants. A highly detailed and structured data bank exists on western pine beetle populations at Blodgett Forest for the last decade (Stark and Dahlsten, 1970; Dahlsten, 1971) and at Bass Lake (Bedard and Wood, 1970) and McCloud Flats (Gustafson et al., 1971) for two years. Computer programs are being prepared which will allow these data to be ordered in a variety of ways so that they can be analyzed and used to produce dynamic models of processes that determine abundance. This background, together with inputs developed from other studies in recent years, notably from plant pathology, physiology, soils, and vegetation, enables us to assess when and how photochemical pollutants influence the abundance of western pine beetle and its associated species, and, in turn, plant succession in the mixed-conifer ecosystem.

Similar studies of the mountain pine beetle, Dendroctonus ponderosae, which is also exploiting pollutant-injured ponderosa pine, could be undertaken.

B. Detection and Quantification of Vegetational Changes Resulting from Bark Beetle Activity Induced by Photochemical Pollutants.

The determination of the amount and distribution of producer and consumer biomass, and the rates at which various processes affect their accumulation and utilization, are important aspects in the ecosystem description and analysis. The measurement methods used must recognize and utilize the stand structure and composition in a multi-stage sample framework (Langley, 1969). Aerial photography is the most effective way to gain the maximum information from any measurement made on the ground. Photographs allow identification of bark beetle activity (Caylor and Thorley, 1970; Heller, 1968, 1970) and conifer root diseases (Hadfield, 1970). There is a need to provide this support service to those researchers in all groups who require remote sensing information. This project requires a photography and mapping unit which can consistently and accurately provide:

1. Information about broad classes of vegetation and changes in vegetation for the entire area.
2. Large scale photo support for ground plots established by plant ecologists, soil scientists, entomologists, pathologists, mammologists, ornithologists and others.
3. Up-dated maps.
4. Tables measuring tree mortality and tree establishment trends.
5. Probabilities for sampling frames of photo-detectable characteristics.

C. The Impact of Photochemical Air Pollutants on Soil Arthropods.

In recent years, the importance of soil animals has received increasing attention (Wallwork, 1970). They are significant in a number of areas including the dynamic processes of soil formation, soil fertility as well as nutrient and mineral cycling (Edwards et al., 1970). In addition, the influence of soil animals on pesticide degradation and movement in the soil, as well as on other human waste products, is under investigation (Lechtenstein, 1970; Dunger, 1968).

With the acknowledged importance of soil animals from a number of standpoints, the disruptive effects on the soil community resulting from man's activities should be considered carefully. Some of these influences have been investigated, including pesticides (Davis, 1968; Barrett, 1968; Edwards, 1970), fertilization (Rapapat, 1964), radiation (Edwards, 1970), fire (Buffington, 1967), and agricultural practices (Oliver, 1966). Despite recent interest in these areas, more detailed, long-term investigations are needed, especially in the forest environment where soil formation and fertility are largely dependent on natural processes. The effects of logging, silvicultural practices, road construction and urban encroachment, and, in particular of smog, are becoming increasingly important, especially with the mounting pressure on montane recreational areas (Huhta, 1967; Moritz, 1965). Recent work (Wenz and Dahlsten, unpubl.) indicates that the effect of fire on soil microarthropods can be significant from the standpoint of community simplification. This may be of particular interest with the use of controlled burning as a management tool.

The effect of changes on stand structure and composition caused by photochemical pollutants offers an excellent opportunity to study the concurrent effect on soil microarthropods. Studies already underway (Wenz and Dahlsten, unpubl.) permit comparisons with natural, undisturbed areas. Characteristics of such disturbances can be obtained, i.e., simplification of both numbers of species and number of individuals of each species, rate of recovery, effects on predator-prey systems and trophic level relationships. The pattern of succession, accompanying and affecting changes in the stand following damage by photochemical air pollutants, can be studied, as soil organisms may be important in vegetational succession (Shine, 1971). Studies of forested areas undergoing the rapid changes exhibited in the San Bernardino Mountains should be especially productive.

D. The Impact of Photochemical Air Pollutants on Sucking Insects.

Sucking insects are a widespread and common group of insects in montane forests. Seldom, however, are they of any concern because of their associated natural enemy complex which regulates their population at levels below that which will cause economic concern (Huffaker et al., 1971).

These insects are seldom pests when they do occur in large numbers, but they usually indicate an environmental disruption (Dahlsten et al., 1969). Recent trends in land development of montane areas as well as increased recreation activities in forested areas increases the need for the development of indicators of any adverse impacts from such activities. The incidence of Phenacaspis pinifoliae, the pine needle scale, as well as that of other scales and aphids, provides one of the potentially good indicators for monitoring these impacts.

Personal observation, along with that of others (Buttrick, 1912), indicates that pine needle scale survives better on trees which are under physiological stress. Therefore, the environmental impact of such factors as photochemical air pollutants, soil compaction, overwater or changes of water table relationships, may all influence scale populations which in turn may be a measure of disruption. Matsucoccus aclyptus is presently in outbreak phase on pinyon pine only in Southern California which mav be a symptom of photochemical air pollution injury to the tree or a direct affect on the parasitoid complex (Legner, unpublished data; U. C., Riverside, Dept. of Biological Control, Exp't. Station Project 2729).

Currently, at South Lake Tahoe, investigators are studying a pine needle scale infestation which has resulted from thermal fogging of insecticides for mosquito control (Dahlsten et al., 1969). Luck (unpublished) has shown that the insecticide residue on the foliage is sufficient to cause mortality of the scale parasites. Preliminary information suggests that the tree's physiological state has an effect on the density of scale. Over-mature trees were more heavily colonized by scales. The aphid, Schizolacnus pini-radiatae, was also present in higher numbers immediately following the cessation of fogging, while in untreated areas such increases were not observed.

Both the scale and the aphid have a moderately wide host range (Terry, 1936; Palmer, 1952). The scale very seldom, if ever, causes tree mortality under forest conditions (McDaniel, 1929) and is noted for its large natural enemy complex (Thompson, 1946). The scale is not a vagile animal. Population movements are restricted to the area around the population (Brown, 1958) and hence there would not be a tendency to migrate out of the area in which the disruption was occurring. The scale has only one generation per year and would therefore be most effective as a monitor of chronic effects of photochemical smog. Because the aphid produces many generations per year it could be an excellent monitor of acute effects that may be expressed by diurnal and seasonal variation in exposure to photochemical oxidants.

With the increased impact of man on the forest ecosystem through recreational activity and increasing technology, it is vital that we develop the capability of predicting potentially serious and irreversible environmental damage. The sucking insects appear to have great potential in developing such a capability.

E. The Impact of Photochemical Air Pollutants on Insects that Influence Tree Growth.

Phytophagous insects exert a powerful influence on the growth rate of host plants. Since they feed selectively on only one or a few species, they in turn influence their competitive ability. Those insects which affect commercially important tree species of the mixed-conifer forest have received the most attention.

The pine reproduction weevil, *Cylindrocopturus eatoni*, kills young ponderosa and Jeffrey pines (Eaton, 1942; Stevens, 1965) while the Yosemite bark weevil, *Pissodes yosemite*, kills ponderosa, Jeffrey, and sugar pine (Stevens, 1966). Thus, the age and species composition of young forests can be greatly influenced by these insects. A consequence of such mortality is a change in the growth rate of the non-host species and remaining individuals of the host species.

Other insects directly affect the growth rate of young trees by killing the growing terminal, as does the ponderosa pine tip moth, *Rhyacionia zozana* (Stevens, 1966), or by consuming the foliage, as does the pine needle sheath miner, *Zellera haimbachi* (Stevens, 1959). Defoliating insects such as the Douglas fir tussock moth *Hemerocampa pseudotsugata* not only reduce the growth rate but can kill large trees (Wickman, 1958). Sawflies are another widespread class of defoliators which potentially affect the competitive ability of their hosts (Struble, 1957; Dahlsten, 1961). *Neodiprion abietis* (complex), *N. fulviceps* (complex) and *Zadiprion rhoweri* which attack white fir, hard pines, and pinyon pine, respectively, are important species in Southern California forests.

Non-commercial plants such as oak, manzanita, and bittercherry also support an assemblage of insects which may kill them or affect their growth rate. The western forest tent caterpillar, *Malacosoma californicum* (Stelzer, 1971), and the ceanothus silk moth, *Hyalophora euryalis* (Essig, 1926), are known to feed on a variety of brush plants. During the summer of 1971 there was a spectacular outbreak of the California tortoise shell, *Nymphalis californica*, which caused extensive defoliation of *Ceanothus* spp. in northern California. Until very recently, these plants were classed as woody weeds and any attention devoted to them was directed at killing them so that they could be replaced by desirable species of trees (Bently, 1967). Undoubtedly, photochemical pollutants will influence differentially these brush species and their insectan herbivores.

F. The Impact of Photochemical Air Pollutants on Arthropods Important to the Reproductive Biology of Vegetation in the Mixed-Conifer Ecosystem.

Plant pathogens, vertebrates and invertebrates are all major factors in the reproductive biology system of plants. However, this outline refers specifically to arthropod consumers. Nectar and pollen gatherers are considered as consumers.

Recent studies in pollination biology (Levin, 1970; Levin and Anderson, 1970; Marshall and Jain, 1970) and in seed-consumer ecology (Janzen, 1969) have indicated that arthropod interaction with plant reproductive biology can exert very strong selective pressure on plant survival and distribution patterns. Arthropods play no apparent role as pollinators of the conifer and Fagaceae components of the mixed-conifer ecosystem. However, they are critical to the pollination biology of other major plant species especially in the Rhamnaceae (*Ceanothus*), and Ericaeceae (*Arctostaphylos*). Pollen and nectar production of numerous other plant species, especially the abundant annual ground forms, play an important if not critical role as a food source for many arthropod groups (Arthur, 1962; Leius, 1963, 1967; Syme, 1966; Thorpe, 1938, 1939). For example, forest pest arthropods are parasitized or preyed upon by syrphids, clerids, tachinids, and ichneumonids, among others. These groups, along with such pest groups as the lepidopteran defoliators, require rich sources of amino acids and carbohydrate for reproduction and energy. They obtain these from the abundant flowering plants associated with the forest ecosystem. Simultaneously, they serve the reproductive biology of the plants by acting as pollinating agents.

Studies of seed- and fruit-consumers apply to all plant species. Many studies have described the presence and abundance of seed- and fruit-consumer of conifers and other plants (Keen, 1958; Gashwiler, 1970; Janzen, 1969; Fowells and Schubert, 1956). Generally these studies conclude that a very large proportion (50-100%) of the seed crop is selectively destroyed with such consistency that the structure of the system is directly affected.

Studies on pollination, pollen and nectar production and consumption, and seed- and fruit-consumers could be designed to elucidate mechanisms and interactions most sensitive to perturbations caused by photochemical pollutants. The distribution and abundance of consumers interacting with plant reproduction systems can be identified and their effects analyzed. For example, the impact of decreased growth rate of ponderosa pine caused by photochemical pollutants on the abundance and species composition of the insects associated with the cones and seeds could be readily determined. Our knowledge of the biology and key interactions with Ponderosa pine of such insects as *Conophthorus ponderosae* (Coleoptera: Scolytidae) and *Laspyrezia miscitata* (Lepidoptera: Olethreutidae) is advanced.

G. The Impact of Photochemical Pollutants on Spider-Prey Relationships.

Spiders are the only large class of arthropods all of whose species are uniquely adapted as predators of other arthropods, especially insects. Through their considerable species diversity and their capabilities to exploit numerous insect niches, spiders must exert tremendous pressure in a myriad of ways upon various arthropods in a mixed-conifer ecosystem. The presence in this ecosystem of approximately 150 species representing 30 families has been observed only recently (Dahlsten and Schlinger, unpublished data). Further, spiders occupy all available habitats from those deep in the soil (e.g., Antrodiaetus) to those at the tops of trees (e.g., Paraphidippus).

The importance of spiders to forest management practices was emphasized by Vité (1953), and Kirchner (1964), who advocated using spiders to control forest insect pests. Nevertheless, studies necessary to substantiate the positions suggested by Vité and Kirchner (loc. cit.) have not been forthcoming. Even in the large integrated ecological research program of the "Solling Project", there is a conspicuous absence of data on these ubiquitous predators (Ellenberg, 1971).

During the past 15 years, several useful specific studies have been published concerning spider interactions with litter and soil arthropods (Huhta, 1965; Martin, 1965; Simon, 1966; Clarke and Grant, 1968; Moulder, et al., 1970; Coyle, 1971), and several others concerning spider relationships with certain defoliating insects have also appeared (Turnbull, 1956; Luczak, 1959; Loughton, et al., 1963; Dondale, 1966; Bosworth, et al., 1971). Similarly, a whole series of useful papers concerning spider-mosquito relationships has pointed out the potential value of spiders as biological control agents for this important group (Dabrowsky, 1966-1969).

While the above kinds of studies are quite useful, none attempts to relate, in more than a limited way, the complex interactions that must exist between spiders, primary consumers, other secondary consumers, as well as reducers, to the whole of the ecosystem under study. Since some spiders are long-lived and often move through different habitats during the same or different seasons during their lifetime, we might expect these species to play an entirely different role as predators than those which build webs or those which reside in burrows and are quite sedentary.

Spiders often reach extremely high densities, even as high as 50/cu ft (Schlinger et al., 1960a), and, at these densities, internal spider parasitoids (Acroceridae) are quite evident (Schlinger, 1960b). The effect of these parasitoids on spider populations has not been carefully investigated, and since some of these parasitoids as adults are useful pollinators, i.e., Eulonchus spp. (Schlinger, 1960c; Grant and Grant, 1965), certain self-incompatible plants may be greatly affected (through the Eulonchus) by a drop in or the destruction of spider population.

Gertsch (1949) and recently Bristowe (1971) suggest that spiders in general have little preference for prey. However, considerable specificity has been noted (Schlinger, unpublished data).

Spider-prey relationships could be elucidated concurrently with the preceeding studies of soil arthropods, defoliators, sucking insects, and insects that influence plant reproductive biology. Comparative studies of spiders in these diverse habitats and in portions of the mixed-conifer ecosystem exposed to high and low levels of photochemical pollutants offer considerable promise in locating some of the more subtle but crucial impacts of such pollutants on this ecosystem.

H. The Impact of Photochemical Pollutants on Insectivorous Birds.

Previous studies in California (Dahlsten and Copper, unpublished) have shown that hole-nesting birds are an important component of the natural control complex of several forest insect pests. In addition, the hole-nesting species, particularly the mountain chickadee, lend themselves to study because they nest readily in artificial nesting sites. Nest boxes have been used successfully in California for six years (Dahlsten and Copper, unpublished).

The effectiveness of birds as predators of specific insect species has been debated, namely that avian predators are extremely important at low insect population densities but are not important mortality agents during insect epidemics. Insectivorous birds have been studied extensively in the Old World (Bruns, 1960; Poznanin, 1956) but have been ignored, by comparison, in North America, particularly the hole-nesting species. Studies by Buckner and Turnock (1965) and Coppel and Sloan (1970) have shown the importance of birds in the population dynamics of several defoliators in North America. However, both of these studies concentrated on birds generally, rather than on a single species, although they included hole-nesting species.

The hole-nesting species receiving the most attention in North America have been the woodpeckers. Woodpecker predation on bark beetles has been studied in detail for the spruce beetle, *Dendroctonus* (Otvos, *in* Stark and Dahlsten, 1971). Woodpeckers have also been studied in relation to other woodboring insects (Solomon and Morris, 1970).

Many of the hole-nesting birds appear to be closely associated with certain insect feeding groups (i.e., sucking insects, defoliators, and bark beetles). Thus, any change in age structure or species composition of insect populations caused by the activities of man such as logging, road construction, insect control, home construction and photochemical air pollution undoubtedly will in turn affect the populations of their avian predators.

II. Aquatic Habitats.

Studies on forest mountain aquatic ecosystems require as intense a monitoring program of the extraneous physical and chemical components of the water as would be required for the atmosphere for the study of terrestrial ecosystems. The present water quality monitoring stations operated by the United States Forest Service at a number of locations in the San Bernardino National Forest would be roughly equivalent to the function of the meteorological and monitoring program of the atmosphere to the forest ecosystem as a whole. Data from these monitoring stations should reflect the trends of nutrient flow from the surrounding land masses, and therefore be of major importance to a study of the terrestrial system. Since these nutrients and other physical and chemical qualities of the water affect the aquatic flora and fauna, the data from the monitoring systems could be used to study the influences of these components on aquatic life as well. However, it must be emphasized that the aquatic systems are as fully complex as terrestrial systems, and therefore the amount of information obtained reflects only the amount of expertise and time devoted to the study.

In addition, water quality monitoring systems similar to ones proposed or in operation in the San Bernardino Mountains should be extended to control sites (regions of no oxidant injury to terrestrial fauna). This would permit certain predictions about the amount of nutrient runoff resulting from the impact of atmospheric pollutants on the Terrestrial system.

The flora and fauna of aquatic systems have been receiving greater attention during recent years and a number of scientific studies have demonstrated their usefulness as indicators of water quality (Gaufen, 1957; Hynes, 1960, 1970, and others). Their role in serving as indicators is of major importance, but it is also apparent that an understanding of the interactions of this ecosystem is important in itself in order to interpret the role of aquatic organisms and

and their interactions to the components of the forest ecosystem.

Initially a survey of the aquatic organisms inhabiting water sources in the study area would give some information as to the past, as well as the present, condition of the aquatic systems (Tarzwell and Gaufin, 1953; Gaufin and Tarzwell, 1956; Tarzwell, 1965; Gallup et al., 1970; Howmiller and Beeton, 1971). Changes in the populations of these organisms or displacement by other organisms might be reflected by an increase in a particular species. For example, certain species of insects of public health importance such as mosquitoes, chironomids, simuliids, etc., are adversely or favorably affected by direct changes in water quality. Indirectly, certain predatory species, such as notonectids, dytiscids, Tricoptera, etc., which are important in regulating these insects, might be adversely affected, resulting in an increase in the species pestiferous to man.

The direct impact of air oxidant pollutants on aquatic systems has not been studied extensively. However, an area where the direct impact of oxidants might be measured and followed is the surface microlayer. As pointed out by Parker and Barsom (1970) "...this thin horizontal layer may have considerable ecological importance. Not only is the knowledge of the natural chemical composition of surface microlayers on lakes, streams, and oceans fragmentary but the influences of substances introduced by man, such as petroleum, long chain-alcohols, synthetic pesticides and surface active compounds on the biota which inhabit the microlayer cannot be estimated. We submit that the interaction of the microlayer with both the air and subsurface water may be of sufficient ecological importance as to be a major contributing factor in currently unexplained problems of air and water pollution."

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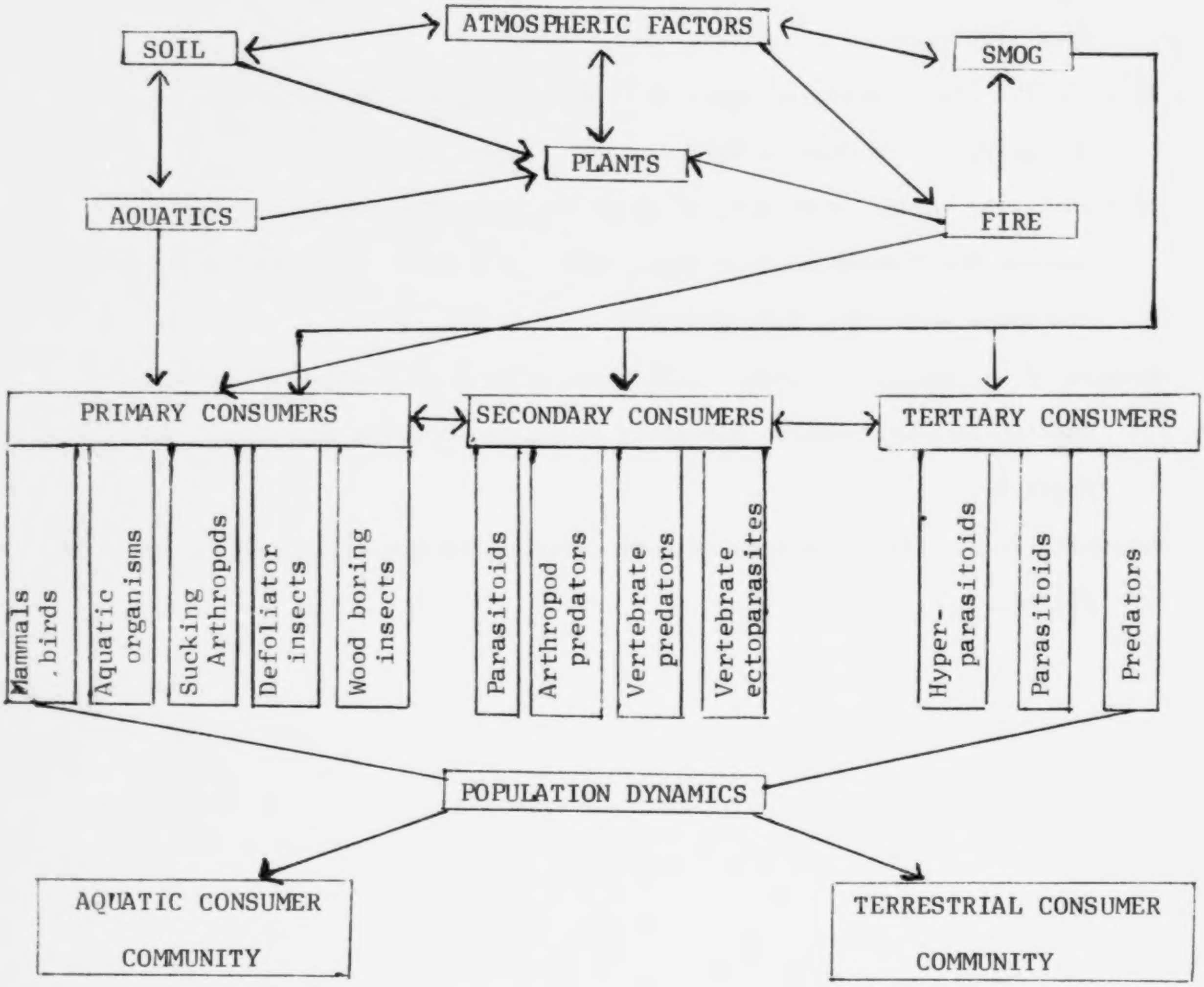
First Approximation: Photochemical Air Pollution and the Consumer Subsystem-- Arthropods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TERTIARY CONSUMERS
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Aquatic organisms
Sucking Arthropods
Defoliator insects
Wood boring insects
Parasitoids
Arthropod predators
Vertebrate predators
Vertebrate ectoparasites
Hyper-parasitoids
Parasitoids
Predators
POPULATION DYNAMICS
AQUATIC CONSUMER COMMUNITY
TERRESTRIAL CONSUMER COMMUNITY

Appendix Section C

APPENDIX: HISTORY OF TREE LOSSES IN THE VICINITY OF LAKE ARROWHEAD, SAN BERNARDINO COUNTY, CALIFORNIA, 1922-1971

by

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December 1971

INTRODUCTION

In order to assess a possible relationship between tree mortality due to bark beetles and air pollution, an attempt was made to reconstruct the history of tree losses in the vicinity of Lake Arrowhead, San Bernardino County, California. The literature used was comprised of reports from the files and archives of the U.S. Department of Agriculture Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California, and the Region 5 Forest Service administrative office in San Francisco, California. The agencies responsible for the reports include the U.S. Forest Service, Bureau of Entomology and Plant Quarantine (BEPQ), California Division of Forestry, Civilian Conservation Corps (CCC), County of San Bernardino, and the Zone 5 Flood Control District. Undoubtedly, many old reports are on file in state and county offices, and on Ranger Districts of the San Bernardino National Forest, but these were not used in the present report.

The use of infestation record sheets facilitated the summarization of the loss figures (Table 2, Figure 2).

AREA OF INFESTATION

The area covered by this report includes Township 2 north, Range 2 west, San Bernardino meridian; T2N, R3W, S.B.M.; and T2N, R4W, S.B.M. (see map). The respective names and abbreviations assigned the townships are Green Valley (GV), Arrowhead (AH), and Crestline (C). Historically, the initial work was done in the Arrowhead township, but later expanded to include Crestline, and then Green Valley. While the infested acreage has probably fluctuated widely over time, the loss figures presented are within one of more of the above townships. Sporadic work was done in the vicinity of Big Bear Lake (T2N, R1E), but was not included in this report.

INTERPRETATION OF TREE LOSS

The history of tree loss due to bark beetles is presented graphically in Figure 1, and tabularly in Table 1. Several points should be kept in mind when interpreting these figures:

1. The figures are for several species of trees. Only in three instances were the losses broken down by tree species, and even then, included a number of "unknowns". The four species represented by the figures are Ponderosa pine, Coulter pine, sugar pine, and Jeffrey pine.

2. More than one infesting insect species is involved. The most commonly-mentioned species are *Dendroctonus brevicomis* LeConte, *D. monticolae* (=*ponderosae* Hopkins), *D. jeffreyi* Hopkins, *Ips* spp., and *Melanophila californica* Van Dyke.

3. Some of the figures presented are estimates of trees infested, others are actual counts, and still others represent only the number of trees treated. For information regarding figures for specific years, see the appendix which contains the infestation record sheets.

4. The figures do not include infested trees removed by logging on private lands, nor do they include trees removed by private property owners who never reported their losses.

5. No exact figure of the spotting efficiency can be given, but it is assumed that 10 to 15 percent of the infested trees in a given area were probably missed. The unsuccessful eradication attempts by the CCC during 1933-34 probably reflect to a certain degree the fact that not all infested trees can be found, even by an experienced spotter.

6. Prior to 1940, occasional attempts were made at spotting and treating trees infested by summer-generation beetles. However, practically all of the control work was done in the winter or spring on overwintering-brood trees. It is therefore assumed that many infested trees were never counted, since the summer generations were largely ignored. With the advent of year-round treatment, summer-brood trees were included in the count.

7. Some years (1928-30 and 1934) show no infested trees. However, this probably indicates waning interest in control activity due to low beetle population levels, rather than a lack of infested trees.

8. The figures do not include "pole-sized" trees which were treated.

From the above, it is concluded that the total tree loss figures for each year are conservative.

HISTORICAL NOTES

The following is a brief chronology of the history of tree losses in the Arrowhead Lake area:

1922-28.--The BEPQ surveyed the area for the first time in March 1922. Control work soon followed. Excellent records of trees spotted and treated were kept by BEPQ personnel. Toward the end of this period, the job was turned over to private landowners, the county forester, and the U.S. Forest Service. By 1928, the infestation was declared "under control". (References 1, 12, 14, 15, 16, 17, 23.)

1929-32.--No control activity due to low beetle populations. (Ref. 19.)

1933-34.--An attempt was made by the CCC to eradicate the bark beetle populations in the area; it failed. Field estimates of the 1931 and 1932 brood trees were made during the treatment period. (Ref. 2.)

1935-38.--Sporadic control attempts were made by private and government agencies. The infestation increased sharply, and it became apparent that a more organized effort at control would have to be made. It should be noted that the figure for 1939 tree loss (Fig. 1 and Table 1) is a field estimate, not an actual count. (Ref. 10, 19, 20, 21, 22.)

1939-52.--The Zone Five Flood Control Board issued funds in 1939 to aid in a cooperative effort with private interests, the U.S. Forest Service, and the California Division of Forestry, to cope with the increasing beetle populations. By 1940, the populations were greatly reduced, and the control program became one of "minimum maintenance". During the period 1947-48, the infestation began to increase, reaching a peak in 1951. (Ref. 11, 18, 19.)

1953-71.--The infestation has persisted at a much higher average level than in previous years. Annual maintenance control work has continued. The infestation reached its greatest peak in 1971. (Ref. 3, 4, 5, 6, 7, 8, 9, 24.)

DISCUSSION

Despite the conservative nature of the annual tree loss counts, the overall trend toward an increase in loss is probably valid. Particularly interesting is the period from 1951 to the present. If the peak loss years during this time can be interpreted as "outbreaks" and the years between as "endemic" periods, it can be seen that both are higher than similar peaks and troughs prior to 1951. Also, it is during the post=1951 period that smog levels began to increase in this area.

While it was not possible to do so for the present report, it would be desirable to inspect the treatment records kept by the various agencies involved to see if they include the species treated. If this information is not available for each year, it might still be possible to calculate a correction factor to estimate the number of infested ponderosa pines.

One of the earliest reports remarked on the presence of bettle-infested trees on or near construction sites. It would be interesting to see if this relationship has continued through the years.

Finally, many of the old reports in the archives of the U.S. Forest Service contain information which might be useful in reconstructing the history of the Lake Arrowhead area with respect to logging, aforestation, fire, and other factors leading to vegetational changes which might affect the beetle populations.

ACKNOWLEDGEMENTS

The personnel of Forest Insect Research, U.S.D.A. Forest Service, Pacific Southwest Forest and Range Experiment Station, and the personnel of the Regional Office of Region Five, U.S. Forest Service, were most cooperative in compiling the information for this report.

TABLE 1.

Annual Loss, 1921-1971

Lake Arrowhead Infestation Area

YEAR	LOSS--(sum/ow)*	
1921	76	
22	40	(13/27)
23	1	
24	207	
25	364	
26	172	
27	48	
1931	12*	
32	15*	
33	280	
35	12	
36	142	(82/60)
37	233	(33/200)
38	270	
39	2279*	(1735/544)
1940	570	
41	62	
42	32	
43	28	
44	41	
45	35	
46	46	
47	99	
48	121	
49	154	
1950	275	
51	1250	
52	925	
53	1488	
54	756	
55	615	
56	568	
57	662	
58	772	
59	855	
1960	804	
61	1869	
62	2552	
63	2432	
64	2661	
65	1750	
66	995	
67	686	
68	722	
69	922	
1970	3820	
71	4145	(3224/921)

* sum = summer generations

ow = overwintering generation

*Field estimates, not actual counts.

TABLE 2

INFESTATION RECORDS

AREA: LAKE ARROWHEAD-CRESTLINE

YEAR		1922			1923			1924			1925	
GENERATION	1921-22 OW	1922 SUM	1922-23 OW	1922-23 OW	1923 SUM	1923-24 OW	1923-24 OW	1924 SUM	1924-25 OW	1924-25 OW	1925 SUM	1925-26 OW
Survey or control work and group	SUR=BEPQ CON=G&P	CON=G&P	SUR=BEPQ CON=G&P	NONE	NONE	NONE	SUR=BEPQ CON=?	NONE 4	NONE 4	SUR=BEPQ CON=G&P	NONE	? 6
# trees found, by spp.	PP=20 CP=44 1 12u	13 u 2	27 u 3				1 u			PP=114 CP=64 JP=2 U=27 U=27 5		
Total volume (MBF), by supp.	PP=43.7 GP=33.33 U=27.0	U=7.58 TT=6.81	U-26.07				NOT GIVEN			PP=79.81 CP=69.83 JP=2.3		
Given Location (section,etc)	AH YES (SEC'S)	AH YES (SEC'S)	AH YES (SEC'S)				NOT^{AH} GIVEN			YES (SEC'S) AH		
REFERENCES REF. NO. & PAGE NOS.	14.pl-5,	15.1-6	15.1-6	23.1	23.1	23pl	23.1-2	23.1-2	23.1-2	23.2-7		

NOTES: 1) 12 additional abandoned trees found; spp. unknown 2) 7 standing and 6 windthrown; spp. unknown; also used 7 trap trees. 3) does not include several group killings of small trees (15 pl.) 4) no work performed, but "many" trees infested. 5) 250 trees (spp. unknown) total, but CA. 70 not treated; 27 unknowns treated by LAC during the winter of '24-'25. 6) Survey report referred it, but not given (23.p7).

INFESTATION RECORDS AREA: LAKE ARROWHEAD-CRESTLINE

YEAR		1926			1927			1928			1929	
GENERATION	1925-26 OW	1926 SUM	1926-27 OW	1926-27 OW	1927 SUM	1927-28 OW	1927-28 OW	1928 SUM	1928-29 OW	1928-29 OW	1929 SUM	1929-30 OW
Survey or control work and group	SUR=? CON=G&P 1	? 1	? 1	CON=G&P SUR=G	? 2	? 2	CON=G&P SUR=G	?	?	NONE	NONE	NONE
# trees found, by spp.	364 u			172 u 3			48 u 4					
Total volume (MBF), by spp.	NOT GIVEN			U=151.42			PP=25.24 CP=3.89 SP=1.79					
Given Location (section,etc)	YES-- AH-C			YES-- MAP AH-C			YES-MAP AH-C					
REFERENCES	17.1-2 12.3 1.P1-2			12.1-8 16.P2			13.1-3 16.P2					

NOTES: 1) Report missing (Funke, 1926). 2) Records vague. 3) 109 trees treated. 4) 18 trees treated.

INFESTATION RECORDS AREA: LAKE ARROWHEAD-CRESTLINE

YEAR		1930			1931			1932			1933	
GENERATION	1929-30 OW	1930 SUM	1930-31 OW	1930-31 OW	1931 SUM	1931-32 OW	1931-32 OW	1932 SUM	1932-33 OW	1932-33 OW	1933 SUM	1933-34 OW
Survey or control work and group	NONE	NONE	NONE	1	1	both= CCC	1	1	both= CCC	2	2	both= CCC
# trees found, by spp.						12 U 1			15 U 1			66 U 3
Total volume (MBF), by spp.						U=8.54 1			U=6.91 1			U=57.89
Given Location (section,etc)						YES- MAP AH-C-GV			YES- MAP AH-C-GV			YES- MAP AH-C-GV
REFERENCES						2.1-22			2.1-22			2.1-22

NOTES: 1) Figures are for abandoned trees found in fall of 1933-apparently an attempt was made to reconstruct history of infestation for 1931 & 1932. 2) No record of work for these periods. 3) Includes Miller Canyon.

x

INFESTATION RECORDS

AREA: LAKE ARROWHEAD-CRESTLINE

YEAR	1934	1935	1936		1937	
GENERATION	1933-34 OW	?	1935-36 OW	1936 SUM	1936-37 OW	1937 SUM
Survey or control work and group	both= CCC		SUR= BEPQ	?	SUR= BEPQ CON=LAC	SUR=BEPQ CON=?
# trees found, by spp.	214 u		10-12 possibly	82 u	60 u	33 u
Total volume (MBF), by spp.	u=207.24		not given	not given	?[2]	
Given Location (section, etc)	YES Map AH-C-GV		AH	AH	AH	YES- Map, SEC'S AH
REFERENCES	2.1-22		20.pl.	21.p2	21.1-3	21.p2

NOTES: 1) "Not more than 10 or 12 of these dead trees were seen in the total distance of 6.5 miles..." pl. 2) "Figures not available." pl.

INFESTATION RECORDS AREA: LAKE ARROWHEAD-CRESTLINE

YEAR		1938		1939		1940			1941	
GENERATION	1937-38 OW	1938 SUM	1938-39 OW	1939 SUM	1939-40 OW	1940 SUM	1940-41 OW	1940-41 OW	1941 SUM	1941-42 OW
Survey or control work and group	CON=LAC		SUR=BEPQ	SMR=BEPQ	CON=CCC BEPQ		both= G&P			both= G&P
# trees found by spp.	U=200		U=270	1735u 5	550pp[3] 544u[4]		U=570 1			U=62 1
Total volume (MBF), by spp.	not given		not given	not given	not given		not given[2]			2
Given Location (section,etc)	AH		AH-C-GV	MAP AH-C-GV	MAP* AH-C-GV		AH-C-GV			AH-C-GV
REFERENCES	22.4.		22.p1,4.	10.1-5	11. pp8-9 *18.p8		19.p4-8			19.p4-8

NOTES: 1) Only treated trees 2) gives ave. DBH 3) estimate of infested trees, but not all in AH-C
4) actual no. trees treated in AH-C-GV 5) estimated loss.

INFESTATION RECORDS AREA: LAKE ARROWHEAD-CRESTLINE

YEAR		1942			1943			1944			1945	
GENERATION	1941-42 OW	1942 SUM	1942-43 OW	1942-43 OW	1943 SUM	1943-44 OW	1943-44 OW	1944 SUM	1944-45 OW	1944-45 OW	1945 SUM	1945-46 OW
Survey or control work and group			both=G&P			both=G&P			both=G&P			both=G&P
# trees found, by spp.			U=32 1			u=28 1			U=41 1			U=35 1
Total volume (MBF), by spp.			NONE GIVEN 2			NONE GIVEN 2			NONE GIVEN 2			NONE GIVEN 2
Given Location (section, etc)			GV-AH-C (maps)			GV-AH-C (maps)			GV-AH-C (maps)			GV-AH-C (maps)
REFERENCES			19.p4-8			19.4-8			19.p4-8			19.4-8

NOTES:
1) Only treated trees
2) Gives ave. D8H

INFESTATION RECORDS

AREA: LAKE ARROWHEAD-CRESTLINE

YEAR	1946	1947	1948	1949
GENERATION	1942-43 OW	1947-48 OW	1948-49 OW	1949-50 OW
Survey or control work and group	both=G&P	both=G&P	both=G&P	both=G&P
# trees found, by spp.	U=46 1	U=99 1	U=121 1	U=154 1
Total volume (MBF), by spp.	NONE GIVEN 2	NONE GIVEN 2	NONE GIVEN 2	NONE GIVEN 2
Given Location (section, etc)	AH-C-GV	AH-C-GV	AH-C-GV	AH-C-GV
REFERENCES	19.4-8	19.4-8	19.p4-8	19.p4-8

NOTES:
1) Only treated trees
2) Gives ave. DBH

INFESTATION RECORDS

AREA: LAKE ARROWHEAD-CRESTLINE

YEAR	1950	1951	1952	1953
GENERATION	1950-51 OW	1951-52 OW	1952-53	1953-54 OW
Survey or control work and group	both=G&P	both=G&P	both=G&P	both=P 5
# trees found, by spp.	Ca.275U 1	Ca.1250U 3	Ca.925U 4	1488U
Total volume (MBF), by spp.	NOT GIVEN 2	NOT GIVEN 2	NOT GIVEN 2	NOT GIVEN
Given Location (section,etc)	AH-C-GV	AH-C-GV	AH-C-GV	AH
REFERENCES	19.p4-8	19.p4-8	19.p4-8	3.p12 24.

NOTES: 1) Actually spotted only 210 trees-275 is an estimate. 2) Gives ave DBH 3) 963 trees treated 4) 841 trees treated. 5) 26,740 acres (Swain).

INFESTATION RECORDS AREA: LAKE ARROWHEAD-CRESTLINE

YEAR	1954	1955	1956	1957
GENERATION	1954-55 OW	1955-56	1956-57	
Survey or control work and group	both=P 1	both=P 1	both=P 1	both=P 1
#trees found by spp.	756U	615U	568U	662U
Total volume (MBF), by spp.	NOT GIVEN	NOT GIVEN		
Given Location (section,etc)	AH-C	AH-C		
REFERENCES	4.p12 24.	5.11 24.	6.11 24.	7.p15 24.

NOTES: 1) 26,740 acres (Swain)

INFESTATION RECORDS

AREA: LAKE ARROWHEAD-CRESTLINE

YEAR	1958	1959	1960	1961
GENERATION		1959-60		
Survey or control work and group	both=P[2]	both=P[2]	both=P[2]	both=P[2]
# trees found, by spp.	772 U	855 U	804 U[1]	1869 U
Total volume (MBF), by supp.	NOT GIVEN	NOT GIVEN		
Given Location (section, etc)	AH-C	AH-C		
REFERENCES	8.p17. 24.	9.p19	24.	24.

NOTES:

1) + 130 abandoned.
2) 49273 Acres (Swain)

INFESTATION RECORDS

AREA: LAKE ARROWHEAD-CRESTLINE

YEAR	1962	1963	1964	1965
GENERATION				
Survey or control work and group	both=G &P 1	both=G&P 1	both=G&P 1	both=G 1
#trees found, by spp.	2552 U	2432 U	2661 U	1750 U
Total volume (MBF), by spp.	NOT GIVEN			
Given Location (section, etc)	AH-C			
REFERENCES	24.	24.	24.	24.

NOTES: 1) 49,273 Acres (Swain)

INFESTATION RECORDS

AREA: LAKE ARROWHEAD-CRESTLINE

YEAR	1966	1967	1968	1969
GENERATION				
Survey or control work and group	both=G 1	both=G 1	both=G 1	both=G 1
#trees found, by spp.	995 U	686 U	722 U	922 U
Total volume (MBF) by spp.	NOT GIVEN			
Given Location (section, etc)	AH-C			
REFERENCES	24.	24.	24.	24.

NOTES: 1) 49273 acres (Swain)

INFESTATION RECORDS

AREA: LAKE ARROWHEAD-CRESTLINE

YEAR	1970		1971	
GENERATION				
Survey or control work and group		both=G 2		both=G 2
# trees found, by spp.		3820 U	3224 U	921 U 1
Total volume (MBF), by spp.		NOT GIVEN		
Given Location (section, etc)		AH-C		
REFERENCES		24.	24.	24.

NOTES:

1) to 9/30/71
2) 49,273 acres (Swain)

ABBREVIATIONS USED IN APPENDIX

SUR:	survey work
CON:	control work
P:	private concerns
G:	government concerns (federal, state, local)
BEPQ:	U.S.D.A. Bureau of Entomology and Plant Quarantine
CCC:	Civilian Conservation Corps
LAC:	Lake Arrowhead Company
AH:	Lake Arrowhead township
C:	Crestline township
GV:	Green Valley township
SEC's:	sections (by number, township and range)
SUM:	summer generation
OW:	overwintering generation
CP:	Coulter pine
JP:	Jeffrey pine
PP:	ponderosa pine
SP:	sugar pine
TT:	trap tree
U:	unknown species, tree
SPP:	species

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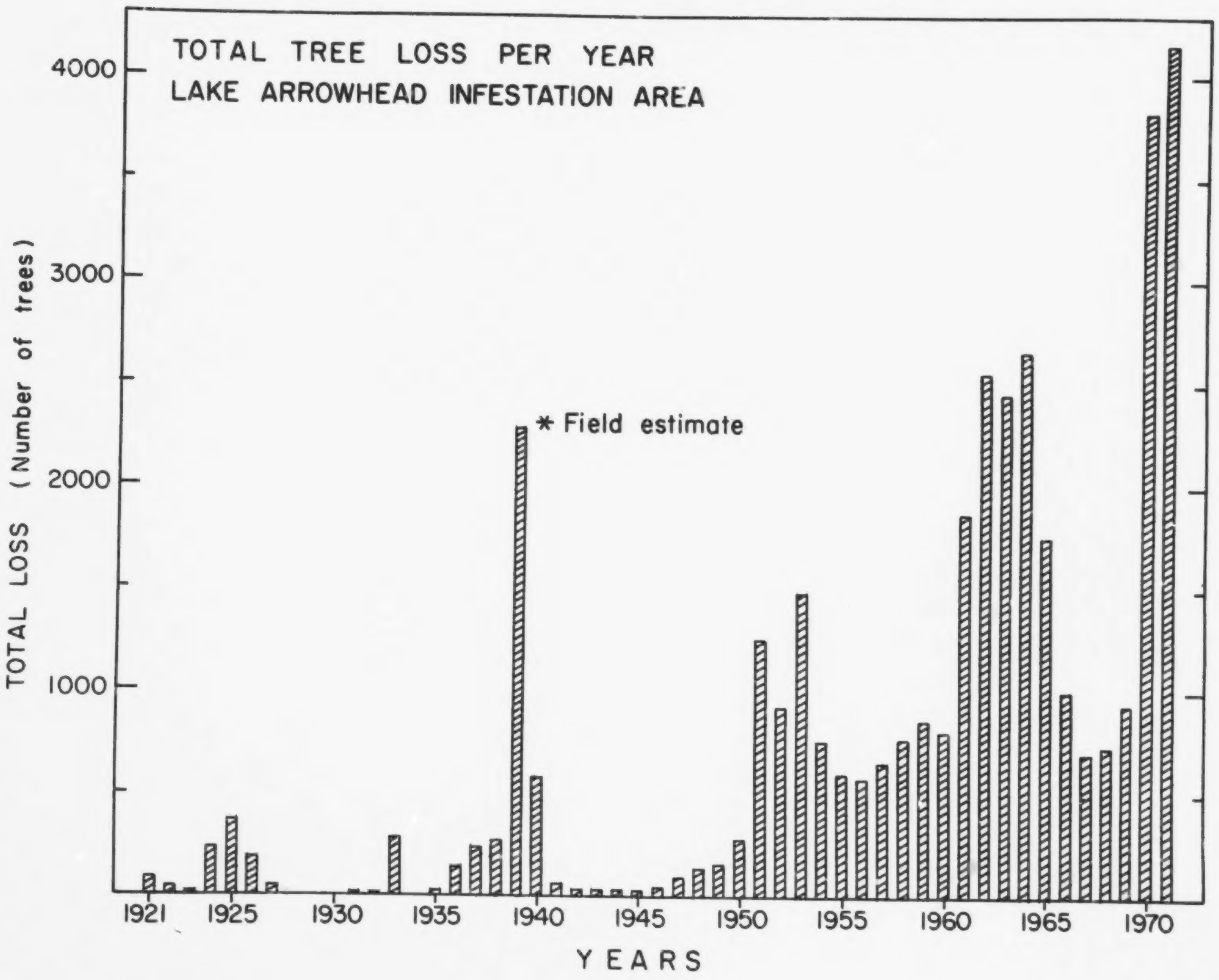
TOTAL TREE LOSS PER YEAR
LAKE ARROWHEAD INFESTATION AREA
* Field estimate
TOTAL LOSS (Number of trees)
4000
3000
2000
1000
1921
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
YEARS

Figure 1.

BARK BEETLE INFESTED PONDEROSA PINES — WESTERN SECTION, SAN BERNARDINO N. F.

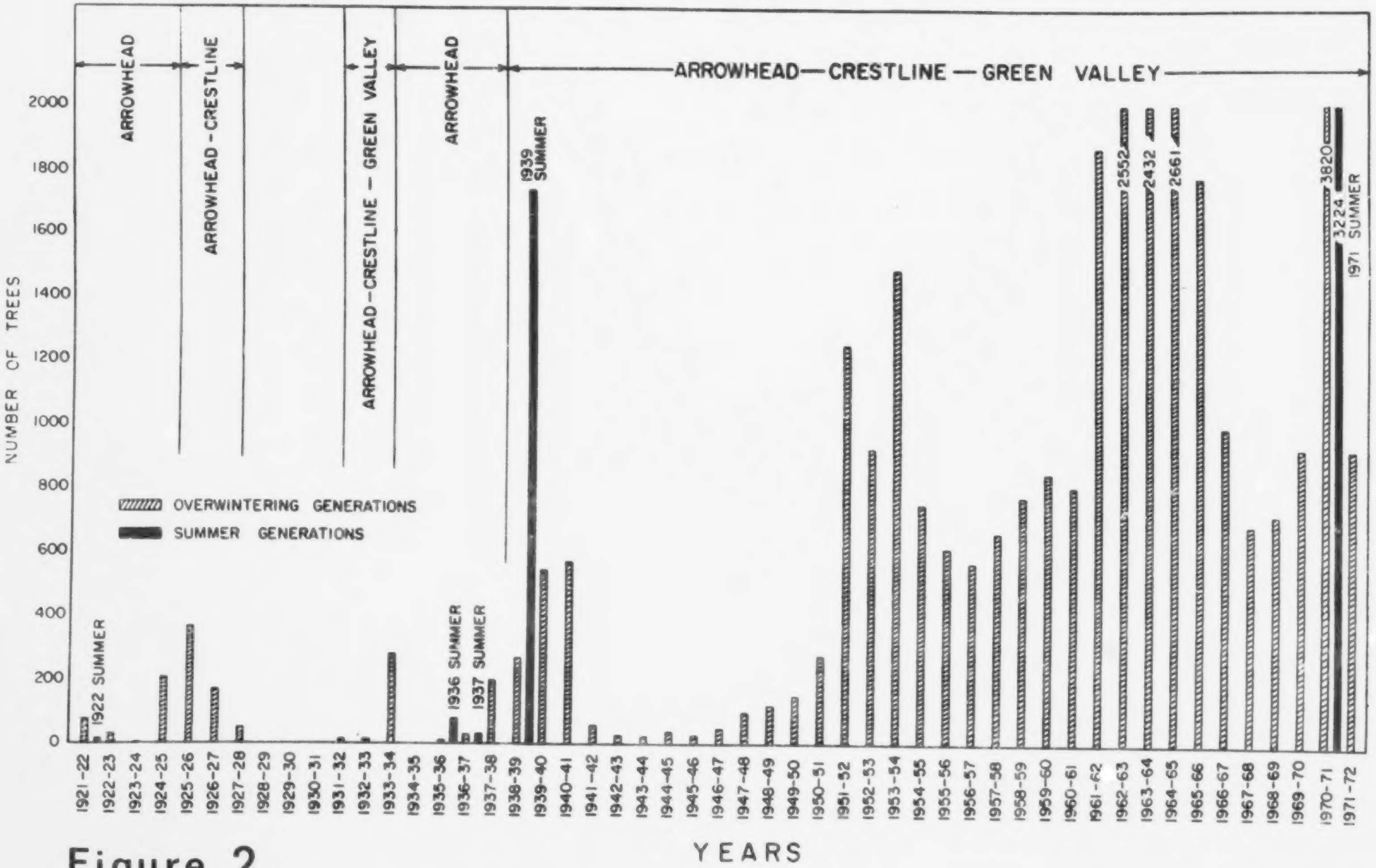

Figure 2.

OXIDANT AIR POLLUTION - METEOROLOGY

by

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OXIDANT AIR POLLUTION - METEOROLOGY

Introduction

Meteorology is involved in a number of ways in determining the impact of air pollution on an area. Atmospheric motions determine the dilution of contaminants both horizontally and vertically and also prescribe the transport of contaminants from source areas to receptors. Consequently the exposure of forest areas in the San Bernardino mountains to oxidant air pollution depends not only upon the atmospheric conditions in these mountains but upon those found in the remainder of the South Coast Air Basin as well.

Meteorology has many impacts on forest ecosystems in the area such as temperatures, humidities, winds, and rainfall. Although the emphasis here is on the impact of air pollution, these other variables are of importance also. For example, the pattern of the strong, hot, dry, northeasterly winds known as "Santa Ana winds" dictates the behavior of the wildfires that periodically devastate large areas of forest and chaparral; and the pattern of rainfall (Fig. D1)influences strongly the distribution of vegetation (Minnich, 1971).

This report, in presenting what is presently known, divides the material into three parts: (A) the large-scale meteorological features affecting the transport and diffusion of air pollution in the South Coast Air Basin, (B) the small-scale atmospheric phenomena generated by the local terrain prescribing the details of pollution distribution, and (C) an estimate of the distribution of oxidant air pollution in the San Bernardino Mountains based on available oxidant concentration data combined with meteorological inference.

The meteorological data were compiled by the network of stations shown in Figures 2 and 3. These observational sites are operated by the U.S. Forest Service, the California Division of Forestry, the California Division of Water Resources, and the Big Bear Fire Department. The oxidant data stem from field investigations made by the U.S. Forest service and the University of California.

A. Large-scale meteorological features

The various types of large-scale weather patterns can be separated into three categories: (a) those producing general on-shore flow, putting the San Bernardino Mountains downwind of the nearly 100 mile expanse of urban and industrial sources between these mountains and the coast, (b) those producing prevailing off-shore flow leaving the mountains upwind of the pollution sources, and (c) those providing the mountains with polluted currents from the basin in some sectors and with opposing currents of unpolluted air in others.

a. On-shore flow

The net daily motion of air across the basin is usually from sea to land. Particularly in Spring, Summer and Fall, the presence of the north Pacific semi-permanent anticyclone off the coast of California provides a northwest flow along the coast. During these seasons a strong daytime sea-breeze coupled with a weak nocturnal landbreeze superposed on this northwest flow produce a net on-shore transport of air. Typically marine air from the coast takes about one day to reach the San Bernardino Mountains.

Associated with this northwest flow are large-scale subsiding motions aloft which create the persistent low level temperature inversion lying immediately above the shallow, cool, moist marine layer. The primary air pollutants are injected into this marine layer whereupon the inversion above, devoid of turbulent mixing motions, inhibits the vertical diffusion of the pollution from the marine layer. The marine layer typically is a little less than 1000 ft deep as it crosses the coastline. In the Spring it tends to be somewhat deeper and in the Fall a little shallower; however, day to day variations tend to be greater than these seasonal changes (DeMarrais et al, 1965).

During the Winter, occasional cyclone passages produce strong on-shore flow devoid of any low level inversion. With strong winds across the source area and no inversion to impede the vertical diffusion of the pollution, the air contamination reaching the San Bernardino Mountains is extremely dilute during these conditions.

b. Off-shore flow

Occasionally the typical weather pattern is interrupted by the development of a strong high pressure area in the Great Basin resulting in a reversal of the general flow. The most striking example of this phenomenon is the strong "Santa Ana wind". In this situation the South Coast Air Basin pollution is swept out to sea and the threat of air pollution in the San Bernardino Mountains is replaced by another hazard, the threat of wildfires.

c. Opposing flows

Depending upon the strength of the high pressure system in the Great Basin and the pattern and strength of the winds aloft, the flow of air from the desert, through the passes and over the ridges, varies from the violent "Santa Ana wind" to a light northerly or easterly flow. In the latter case, the winds may be sufficiently vigorous to halt the advance of the polluted up-slope flow in the passes and on the more exposed slopes. On other occasions, mainly in summertime, the opposing flows are provided by downdrafts under thunderstorms which develop in deep moist currents moving into the mountains from the south and southeast.

B. Small-scale phenomena

The character of the terrain from the coastline inland to the peripheral mountain ranges prescribes the nature of the small-scale meteorological factors which perturb the general flow. The differential heating of land and sea impose the diurnal variation of sea- and land-breeze in the basin, typically developing air motions as vigorous as the general flow upon which they are superposed. The mountain ranges are obstacles to the cool dense marine air and steer it like a polluted stream into the passes on either side of the San Bernardino Mountains. At the same time, the heated daytime slopes of the mountain ranges heat that part of the marine layer coming into contact with them, thus forming a buoyant layer that ascends the slopes to the ridges and peaks. This film of heated air rising along the slopes, often referred to as a thermal chimney, vents polluted air out of the basin.

The heated coastal plain and floors of the valleys leading from the coast to the San Bernardino Mountains systematically raise the temperature of the marine layer as it moves inland. At some point during this journey the marine layer becomes sufficiently warm to destroy the inversion; i.e. air in this upper layer is no longer warmer than the marine layer below. The polluted marine layer is then free to mix vertically with the pollution-free air above and this active dilution results in a systematic decrease in pollution concentrations as the air travels inland. Typically this final demise of the inversion occurs in the mountain passes and in the thermal chimney along the basin-facing slopes. The peripheral ranges, of which the San Bernardino Mountains are a part, then, typically delineate the inland limit of the polluted marine layer trapped beneath the inversion. At and beyond this limit a rapid decrease in concentrations takes place via vertical diffusion providing the marked improvement in visibility from the coastal side of the peripheral ranges to the desert.

At night a weak off-shore flow replaces the more vigorous daytime on-shore flow in the basin. The mountain slopes and canyons become the site of drainage winds. Mountain basins such as that at Big Bear impound the chilled air moving down the slopes to form a strong nocturnal temperature inversion. In general, then, the nighttime hours are characterized by a retreat of air from the mountains.

C. Distribution of oxidant in the San Bernardino Mountains

Measurements of the oxidant concentrations in the San Bernardino Mountains have been made since 1967 (Miller, 1971). These surface observations have been supplemented by measurements aloft during several intensive field experiments (Edinger et al, 1970). These studies reveal several important facets in the distribution of oxidant in the mountains.

At elevations above the top of the inversion (average about 3500 ft) the exposure to oxidant falls off with distance downwind. The graph in Fig. D4, based on October 1967 data, illustrates that both the average daily total oxidant maximum and the number of hours when total oxidant exceeded 0.10 ppm decrease with distance downwind from Rim Forest (5,780 ft).

Observations made on the slopes below and upwind of Rim Forest in June 1970 indicate that the maximum concentration actually occurs at about 3500 ft. This is the typical elevation of the top of the temperature inversion and is the altitude on the mountain slopes where the rapid vertical diffusion of polluted marine air begins. The concentrations tend to decrease slightly with distance downslope (upwind) from the 3500 ft contour. Some features of the vertical distribution of pollution in the marine layer prior to its arrival at the mountains suggest reasons for this result.

The measurements made by aircraft over the urban source areas upwind of the mountains indicate that the pollutants are not uniformly distributed vertically in the layer beneath the inversion. Figures D5 and D6 are typical examples of soundings of oxidant and temperature from the surface up through the marine layer, inversion layer and the air above.

They illustrate the tendency for a maximum concentration near the base of the inversion. Frequently this maximum actually occurs in the very lowest layer of the inversion. Earlier observations (Edinger, 1963) of high moisture content in the lowest part of the inversion support the hypothesis that the uppermost part of the marine layer is a layer of convective debris that accumulates just below the warm dry inversion air above. Being warmer than the remainder of the marine layer below, this debris becomes an extension downward of the inversion. It does not mix subsequently with the marine layer below and so is not subject to those reactions with new material introduced at the ground which consume oxidant. Consequently the photochemical processes which create the oxidant proceed unopposed in this lowest part of the inversion.

Not infrequently the aircraft soundings also revealed layers of high oxidant content completely imbedded within the inversion as illustrated in Figures D7 and D8. Visual and photographic evidence suggests that these layers of photochemical aerosol are injected into the inversion from the polluted thermal chimney moving up the slopes of the San Gabriel Mountains on the north. Encapsulated in the inversion where no mixing motions exist to diffuse and disperse them and where no destructive reactions operate, these layers also achieve high oxidant concentrations. These layers come into contact with the slopes of the San Bernardino Mountains near the 3500 ft level. This is the level at which maximum oxidant concentration is observed.

The basic processes working in concert to produce the vertical profile of oxidant delivered from the source area to the slopes of the San Bernardino Mountains are summarized in the sketches shown in Fig. D9. On days when the inversion is weak (i.e. when there is little difference in temperature from the base to the top of the inversion), it will be destroyed by convective erosion from below prior to its arrival at the San Bernardino Mountains. On such days the polluted current will be deep and dilute upon arrival at the mountains and fairly uniform vertically. On the majority of days, however, the inversion is strong enough to reach the slopes of the San Bernardino Mountains intact, although thinned and weakened substantially by the erosion from below. The final breaking of the inversion occurs in the thermal chimney. At this point, typically 3500 ft., the pollution encapsulated in the inversion is released into the upslope flow. This is a possible explanation for the maximum in concentrations observed at this level.

Fig. D10 shows the area between 3000 and 4000 ft. on the basin-facing slopes of the San Bernardino Mountains where the maximum oxidant concentrations are to be expected. This area extends laterally from Cajon Pass to San Gorgonio Pass. Since Cajon Pass at its summit has an elevation of 3500 ft., the zone of maximum concentration should terminate near the summit because at this elevation even the uppermost part of the inversion is finally affected by surface heating and is destroyed. However, in San Gorgonio Pass the summit is at approximately 2500 ft; therefore, the polluted air, with inversion intact, can flow through the pass for some distance before the inversion is broken. Consequently, the zone of maximum concentrations should extend some distance around the south side of the San Bernardino Mountains into the desert. Just how far depends upon such variables as the strength of the inversion, the wind speed, and the time of day, in addition to the height of the top of the inversion.

It is difficult to specify the lateral variation of oxidant concentrations along this maximum zone. Some variability is expected since the broad polluted stream from the basin source area is not homogeneous laterally. In addition, the trajectories from the sources vary from day to day and also influence the lateral distribution. The scant data taken immediately upwind of the mountains substantiate this conclusion. Table D1 shows the mean daily maximum values of oxidant at Riverside and San Bernardino for the years 1968, '69, and '70. During this period the values at Riverside consistently exceeded those at San Bernardino by close to 33%. If this is representative of the lateral distribution of oxidant before it reaches the mountains, a similar gradient of concentration along the 3500 ft contour can be expected.

As previously indicated, concentrations also decrease with distance downwind from the 3500 ft contour on the basin-facing slopes. Taking this into account along with the lateral gradient described earlier, a simplistic typical horizontal distribution of oxidant throughout the mountains can be projected. A host of local terrain effects distorts this general picture, as do anomalous local weather events. Summer thunderstorms, in particular, profoundly alter the pollution distribution in the mountains. Minnich (1967) has made a study of these storms and the distribution of thundershowers over the range. Fig. D11 gives a distribution of the rain days resulting from summertime convection. The locations having the maximum number of rain days are likely to be the sites experiencing diminished air pollution. The downdrafts produced by the precipitation oppose the upslope flow which otherwise delivers pollution from the source areas. Furthermore, the shade afforded the slopes by the clouds dramatically weakens the heating responsible for the upslope motion. The difference in the number of rain days from place to place within the range is seen to be substantial, varying from 4 per summer season at the west end to 30 near the summit of San Gorgonio Peak.

Another complication affecting the distribution of oxidant on the slopes is the lateral distribution of oxidant imbedded in the inversion before it reaches the range. If this source of oxidant, as suggested earlier, is largely responsible for the maximum concentrations observed at the 3500 ft level on the slopes, the lateral distribution of oxidant within the inversion could influence the pattern of oxidant across the range at all levels above 3500 ft. However, until observations concerning this lateral distribution in the inversion can be made, no positive conclusions can be drawn.

Other influences are introduced by smaller terrain features within the mountains such as south-facing vs. north-facing slopes, box-canyons vs. through-canyons, broad valleys and basins vs. deep narrow canyons. All these have their own unique influence on the transport and turbulent diffusion of polluted air passing over and through them. Each location requires its own special study as regards these micrometeorological details, a task beyond the scope of this discussion.

With the limited information available, a description of the impact of air pollution and its geographical distribution throughout the San

Bernardino Mountains must be in the broadest of terms. To summarize, the impact of oxident pollution depends upon the following factors related to atmospheric conditions: a) whether the site is facing the basin (south-facing) or facing the desert (north-facing), b) whether the basin-facing slopes are above or below 3500 ft, c) the distance downwind on slopes above 3500 ft when the wind is from the basin, d) the average wind speed from the basin and e) the frequency of summer thundershowers at the site.

Among the factors listed above only the effect of the wind speed has not been discussed. Wind speed influences the reactions between oxidant and the trees. Assuming that the rate at which the reactions take place increases with heavier oxidant concentration, the rate at which the oxidant is delivered (the wind speed) is involved. Thus, the greater the wind speed the more rapidly oxidant is replenished.

The average wind at a location is affected greatly by the terrain. The windiest locations are: (a) passes low enough to admit the marine layer still capped by the inversion, (b) tops of long steep slopes, (c) heads of canyons on the sunny side of the range, and (d) the crests of steep low ridges extending out into passes across the general flow.

Since our concern lies with forests susceptible to oxidant damage, the area of concern is limited, as shown on the map in Fig. D10, to those areas where ponderosa and Jeffrey pines are found. These areas all occur above the 3500 ft. contour which, as discussed above is the site of the maximum oxidant concentrations.

Certain locations in the San Bernardino Mountains have been selected to identify the places where the greatest impact of oxidant air pollution on ponderosa and Jeffrey pine forests may be expected. These maximum impact areas are: (A) Rim Forest, (B) Camp Angeles, and (C) the upper end of Mill Creek canyon above 6000 ft. The sites selected where impact should be minimum are (D) Big Pine Flat and (E) the east end of the Big Bear Basin. These selections are not all inclusive nor are they absolute, but should be considered as best estimates subject to revision when more complete data coverage in the mountains becomes available. Certainly the sparse data currently at hand suggests great variability from place to place and from time to time. Consider, for example, the data in Table D2, which contrasts daily maximum oxidant values at Rim Forest with those at the east end of Big Bear Lake for August and September 1968. As our simple criteria would require, the values at Big Bear are much lower than those at Rim Forest. However, Table D3, indicating the highest daily maximum values reported at the two stations, shows that for both months the highest individual readings were reported at the Big Bear station. Some special array of meteorological and source factors combined to deliver higher concentrations of oxidant to the more remote location on these days.

The conclusions reached in this section were constructed on slim data and therefore must be considered very tentative. Nevertheless, the data available does permit a few firm conclusions. The San Bernardino Mountains encounter air with oxidant concentrations exceeding the State ambient air quality standards every day from May through September. In its 1970 Annual Report the San Bernardino County Air Pollution Control District reported that the standard (0.10 ppm of oxidant) was exceeded in the city of San Bernardino on 167 days during that year. The analysis above indicates the concentrations in the San Bernardino Mountains downwind of the city are even higher. The data also clearly indicates that marked differences in the impact of air pollution occur within the range; in particular, marked decreases in the downwind direction above 3500 ft.

More detailed analysis of oxidant distribution in the range requires more complete networks of data at the surface and aloft, within the mountain range and upwind. In the last analysis, however, the most telling data concerning the meteorological details may well be non-meteorological information, such as the detailed distribution of oxidant damage to vegetation throughout the San Bernardino Mountains. The initial efforts in this field by Miller (1971) and Wert (1969) have already provided important insights.

Acknowledgements

Special thanks are due Paul Miller and Rich Minnich for providing not only firm facts and figures but some very suggestive observations that otherwise would remain invisible between the rows and columns of figures.

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Table Dl. Yearly mean of the daily maximum hourly average Concentration of oxidant for the cities of San Bernardino and Riverside. (ppm)

	San Bernardino	Riverside
1968	.09	.13
1969	.11	.15
1970	.12	.15

Table D2. Average daily maximum oxidant concentration at Rim Forest and Big Bear for August and September 1968. (ppm)

1968	Rim Forest	Big Bear
Aug	.21	.12
Sept	.17	.08

Table D3. Highest daily maximum oxidant concentration recorded at Rim Forest and Big Bear for August and September 1968. (ppm)

1968	Rim Forest	Big Bear
Aug	.32	.37
Sept	.31	.33

Figure legends

Fig	
D1	Average annual rainfall in San Bernardino Mountains, 1870-1970, (inches)
D2	Weather stations recording observations at 14:30 (USFS) or 14:00 PST
D3	Weather stations making night wind observations and fire lookout observations (07:00 PST)
D4	Average daily total oxidant maximum and number of hours when total oxidant exceeded 0.10 ppm, as a function of distance downwind from Rim Forest, October, 1967.
D5	Vertical soundings of oxidant and temperature, 16:20 PST, June 20, 1970, Rialto-Miro airport.
D6	Vertical soundings of oxidant and temperature, 13:44 PST, June 19, 1970, El Monte.
D7	Vertical soundings of oxidant and temperature, 13:28 PST, June 20, 1970, Santa Monica.
D8	Vertical soundings of oxidant and temperature, 13:28 PST, June 20, 1970, Santa Monica.
D9	Schematic vertical cross-sections illustrating meteorological features that influence the vertical distribution of air pollution in the South Coast Air Basin.
D10	Map of San Bernardino Mountains. Elevation in thousands of ft mean sea level given by numbers of contours. Stippled area denotes location of ponderosa and Jeffrey pines. Hashed area denotes zone of expected maximum oxidant concentration.
D11	Number of thunderstorm rain days, June 28 - Sept 10, 1967.

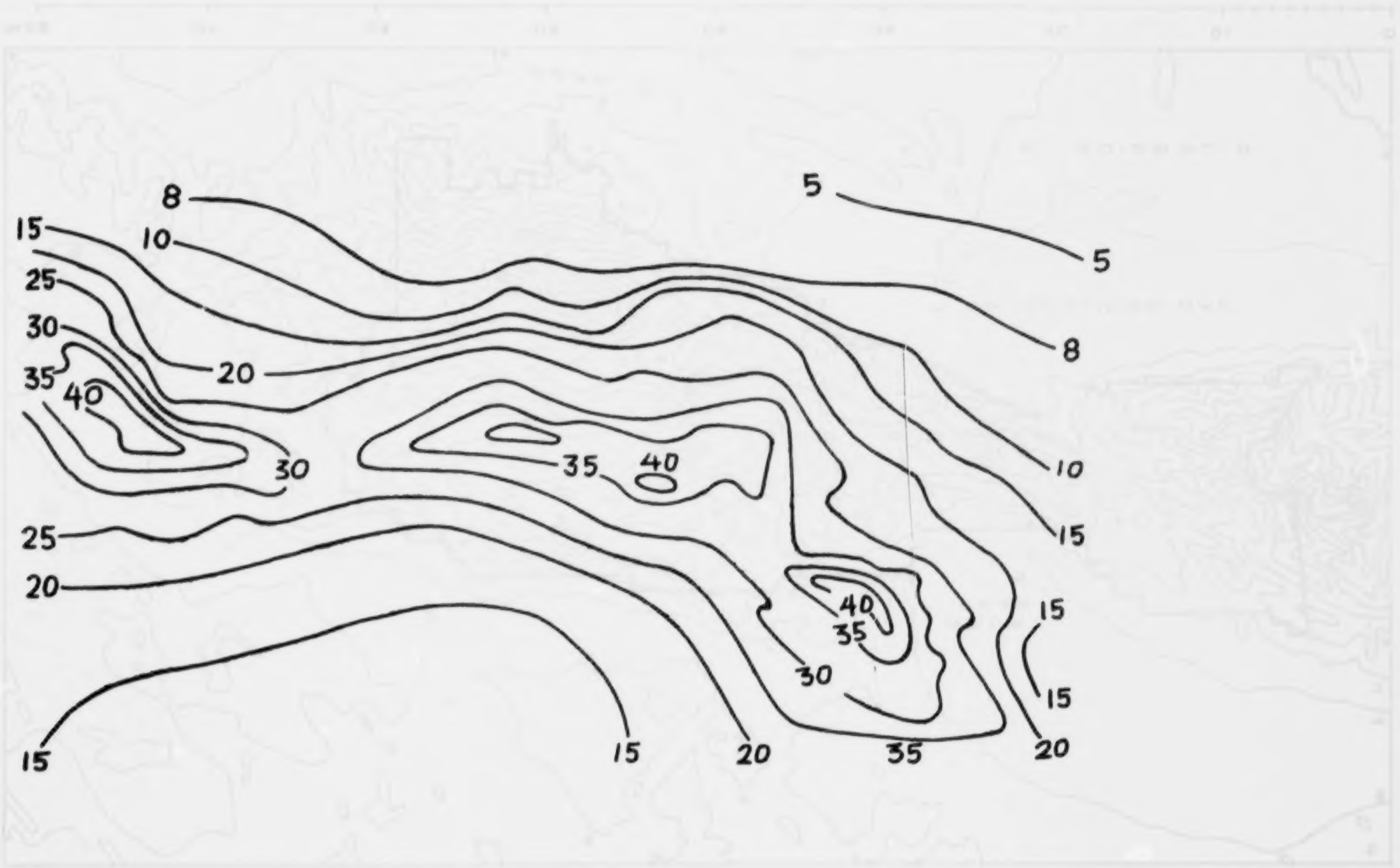

8
5
5
15
10
25
30
20
35
40
30
35
40
8
10
15
25
20
40
35
15
30
15
15
20
35
20

Figure D-1

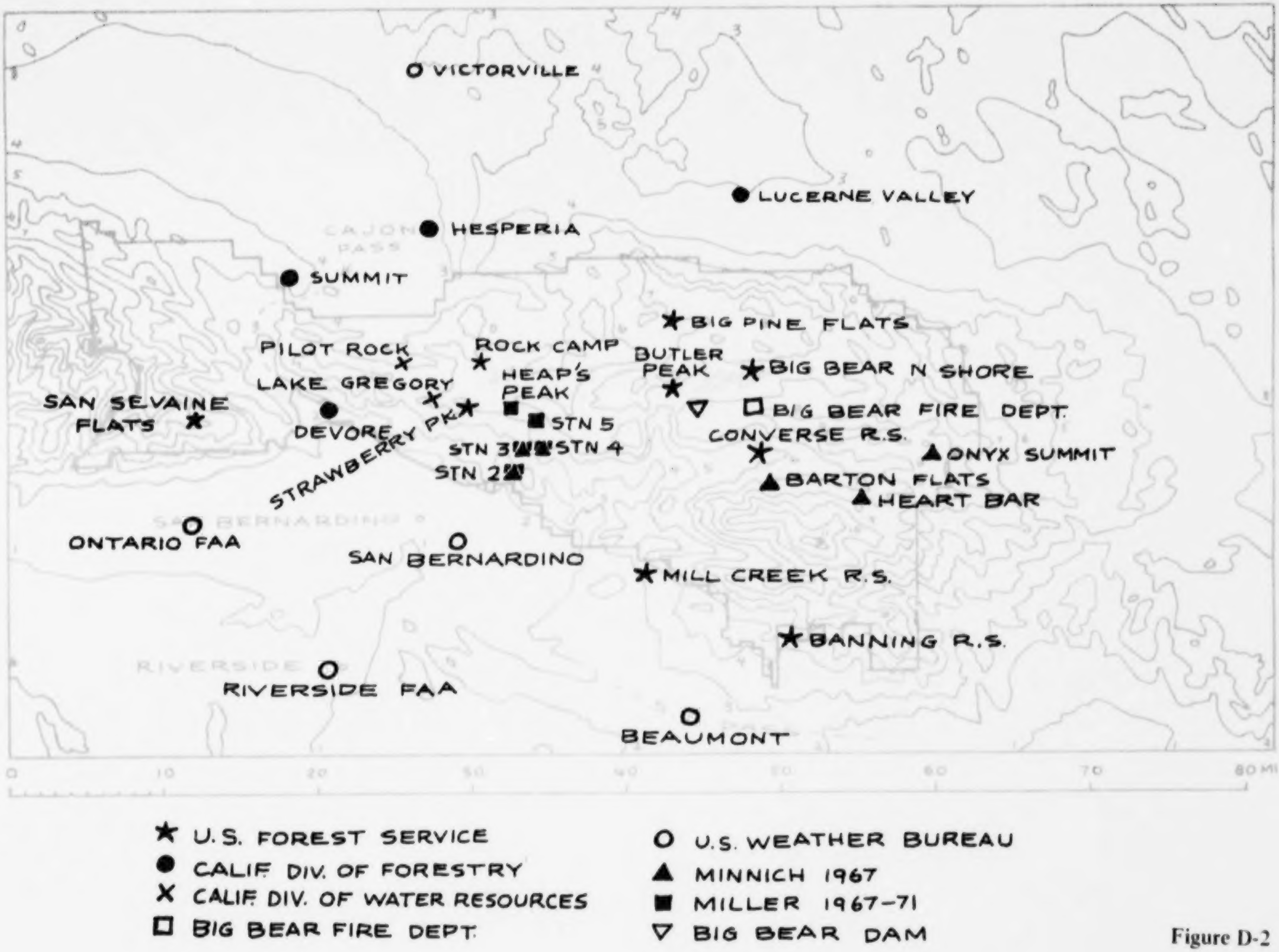

VICTORVILLE
LUCERNE VALLEY
HESPERIA
CAJON PASS
SUMMIT
BIG PINE FLATS
PILOT ROCK
ROCK CAMP
BUTLER PEAK
BIG BEAR N SHORE
LAKE GREGORY
HEAP'S PEAK
SAN SEVAINE FLATS
DEVORE
STRAWBERRY PK.
STN 5
BIG BEAR FIRE DEPT.
CONVERSE R.S.
STN 3
STN 4
ONYX SUMMIT
STN 2
BARTON FLATS
HEART BAR
SAN BERNARDINO
ONTARIO FAA
SAN BERNARDINO
MILL CREEK R.S.
BANNING R.S.
RIVERSIDE
RIVERSIDE FAA
BEAUMONT
0
10
20
30
40
50
60
70
80 MI
★ U.S. FOREST SERVICE
● CALIF. DIV. OF FORESTRY
× CALIF. DIV. OF WATER RESOURCES
□ BIG BEAR FIRE DEPT.
○ U.S. WEATHER BUREAU
▲ MINNICH 1967
■ MILLER 1967–71
▽ BIG BEAR DAM

Figure D-2

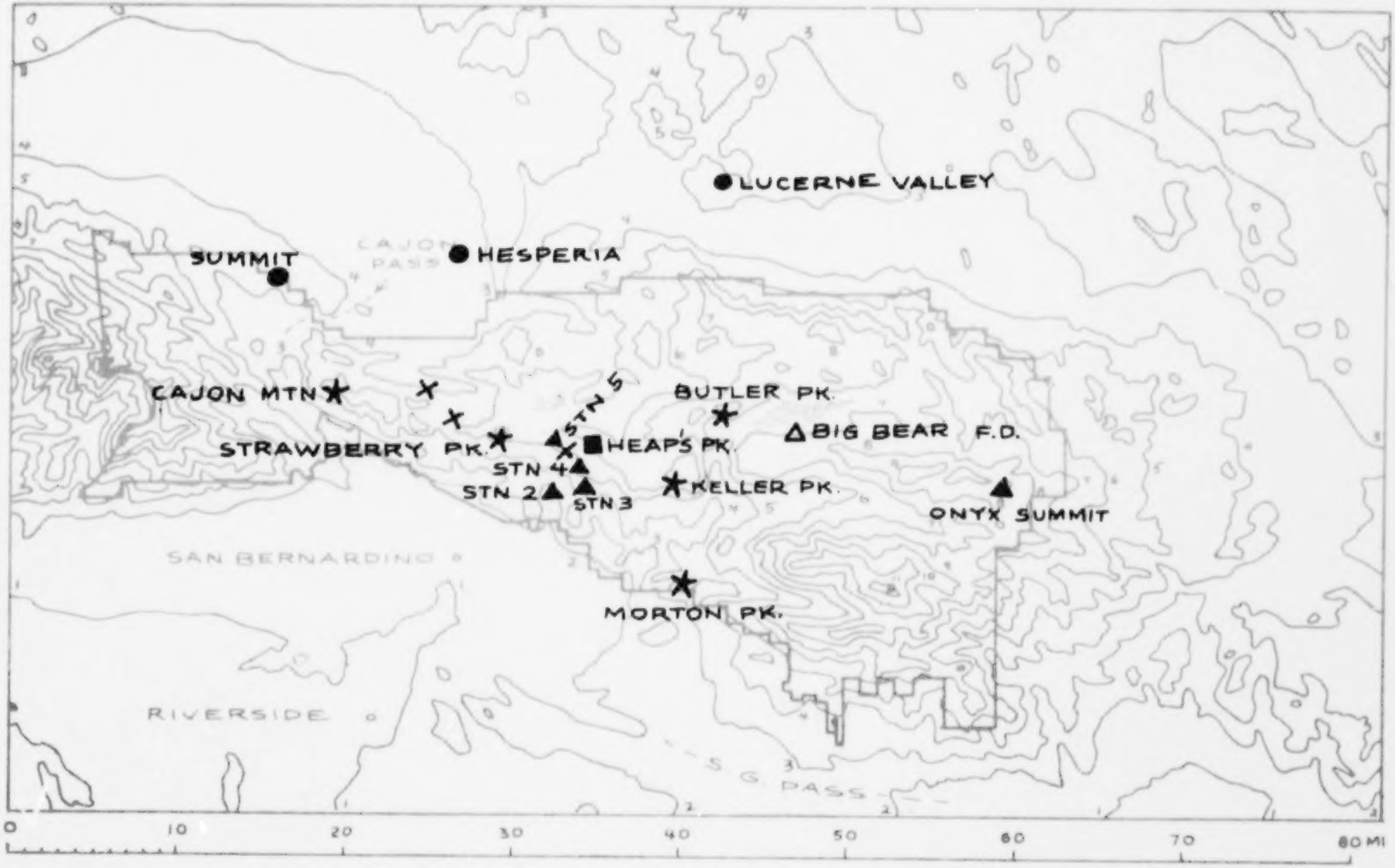

LUCERNE VALLEY
SUMMIT
CAJON PASS
HESPERIA
CAJON MTN
STN 5
BUTLER PK.
STRAWBERRY PK.
HEAPS PK.
BIG BEAR F.D.
STN 4
STN 2
STN 3
KELLER PK.
ONYX SUMMIT
SAN BERNARDINO
MORTON PK.
RIVERSIDE
S G PASS
0
10
20
30
40
50
60
70
80 MI

Figure D-3

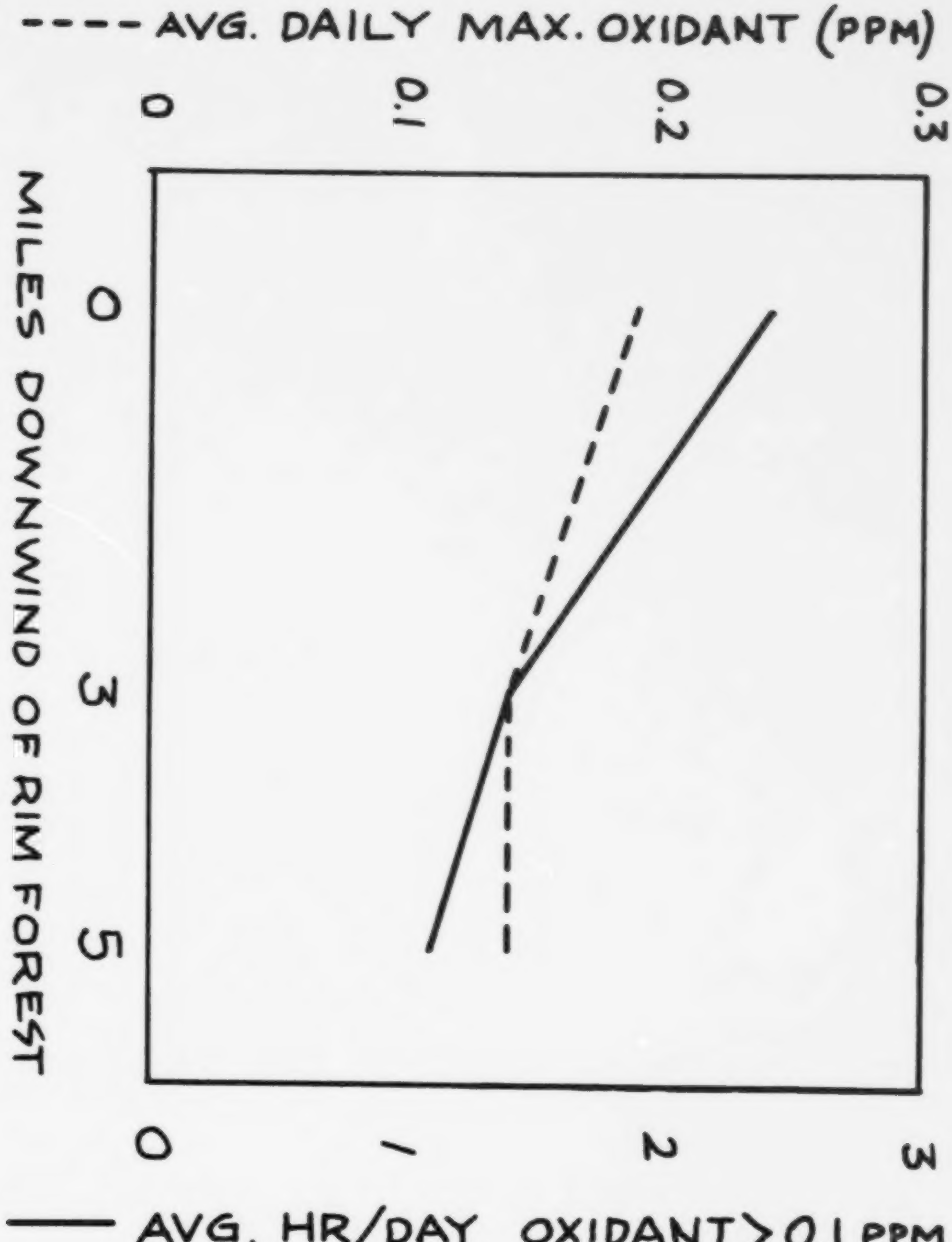

---- AVG. DAILY MAX. OXIDANT (PPM)
0
0.1
0.2
0.3
MILES DOWNWIND OF RIM FOREST
0
3
5
0
1
2
3
— AVG. HR/DAY OXIDANT > 0.1 PPM

Figure D-4

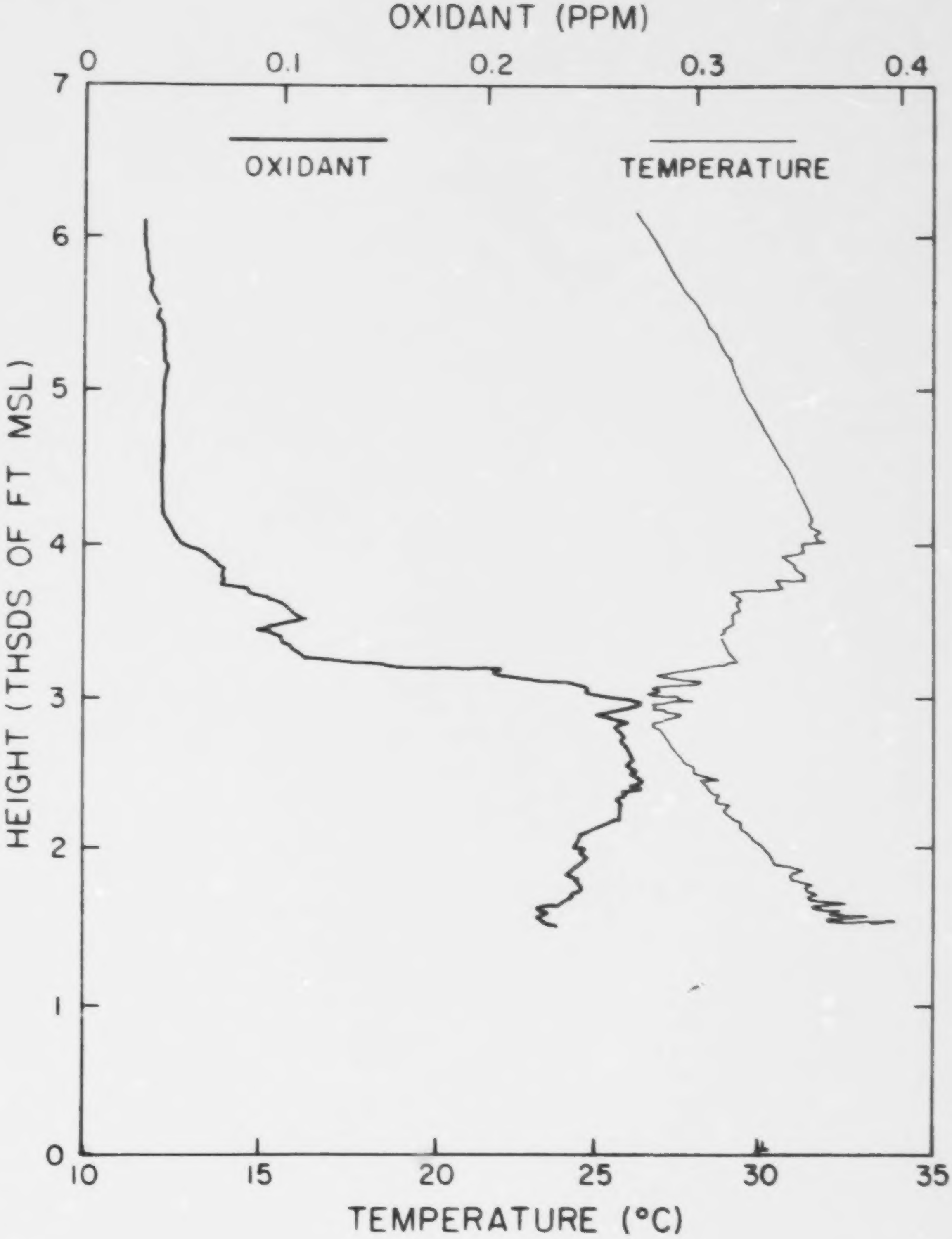

OXIDANT (PPM)
0
0.1
0.2
0.3
0.4
OXIDANT
TEMPERATURE
HEIGHT (THSDS OF FT MSL)
7
6
5
4
3
2
1
0
10
15
20
25
30
35
TEMPERATURE (°C)

Figure D-5

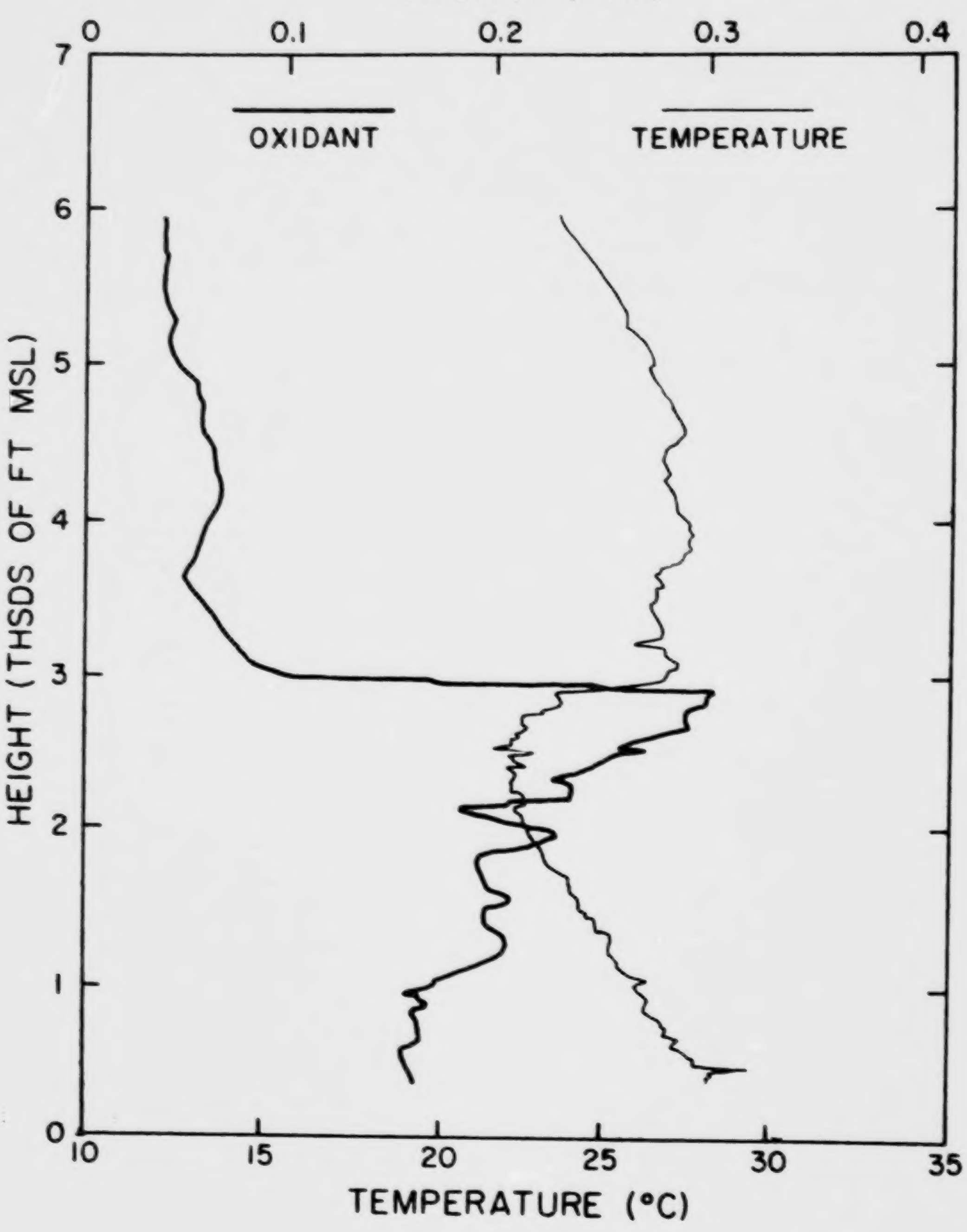
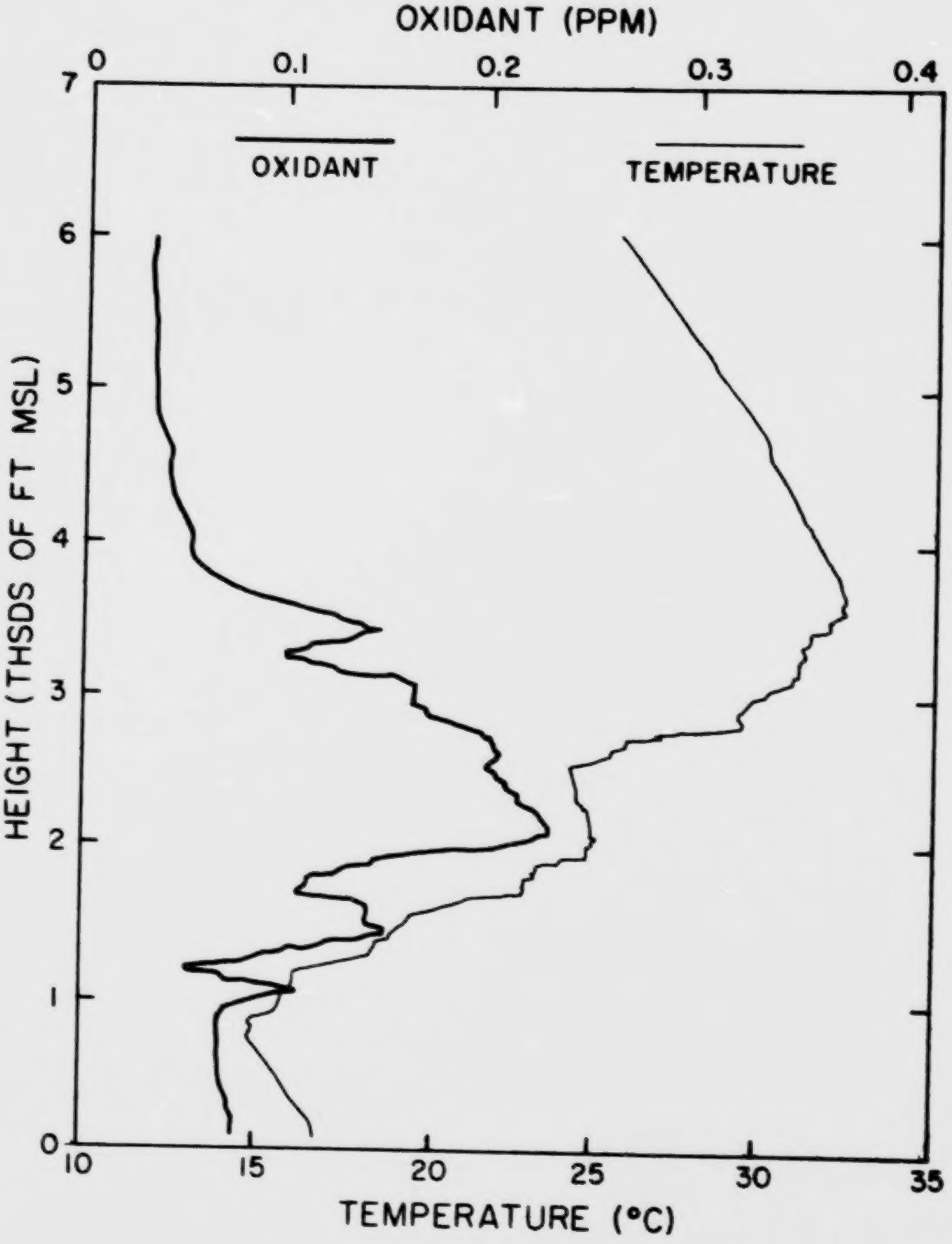

OXIDANT (PPM)
0
0.1
0.2
0.3
0.4
OXIDANT
TEMPERATURE
HEIGHT (THSDS OF FT MSL)
0
1
2
3
4
5
6
7
10
15
20
25
30
35
TEMPERATURE (°C)

Figure D-6


OXIDANT (PPM)
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0.1
0.2
0.3
0.4
OXIDANT
TEMPERATURE
HEIGHT (THSDS OF FT MSL)
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6
5
4
3
2
1
0
10
15
20
25
30
35
TEMPERATURE (°C)

Figure D-7

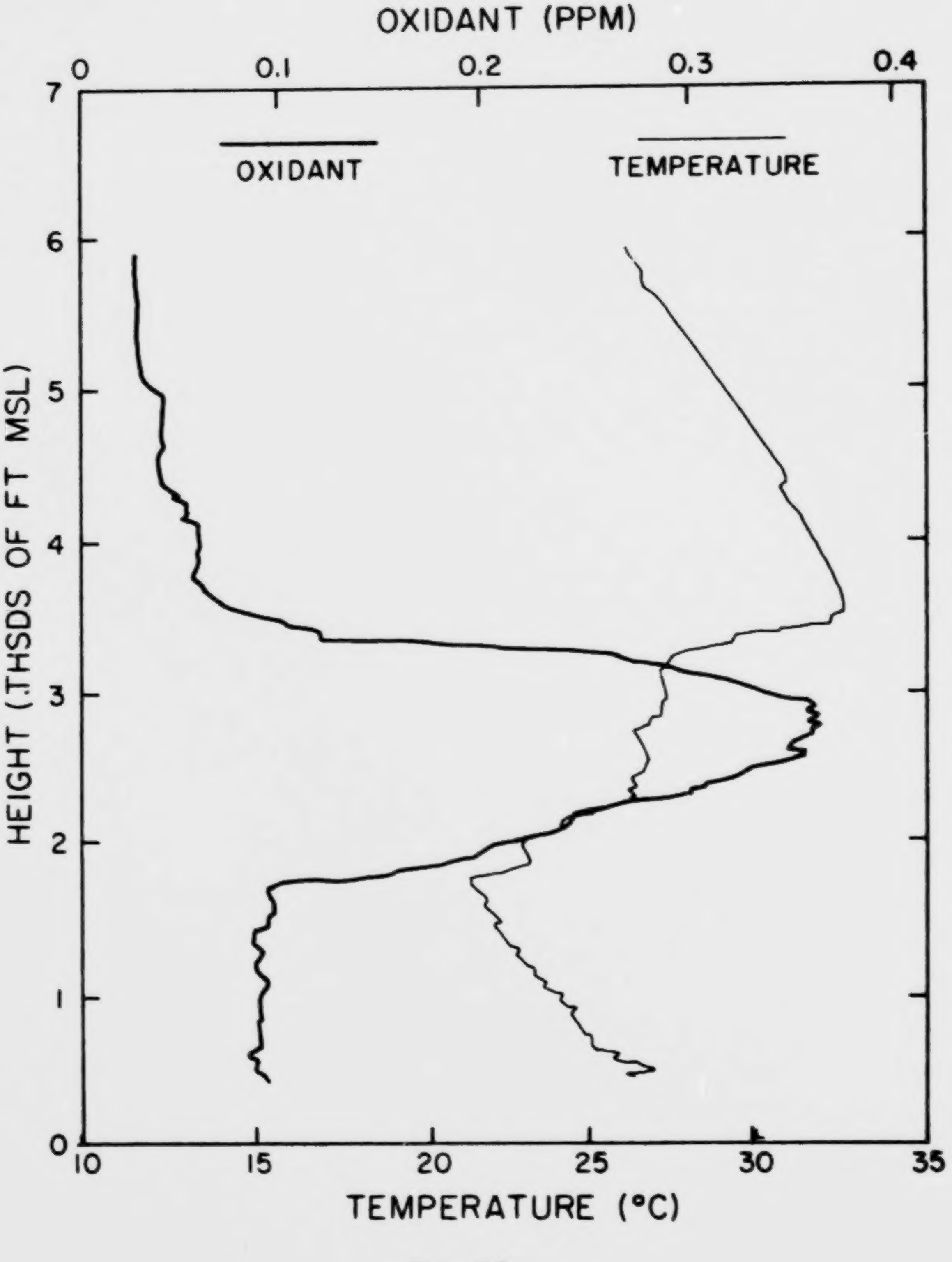
OXIDANT (PPM)
0
0.1
0.2
0.3
0.4
OXIDANT
TEMPERATURE
HEIGHT (THSDS OF FT MSL)
0
1
2
3
4
5
6
7
10
15
20
25
30
35
TEMPERATURE (°C)

Figure D-8

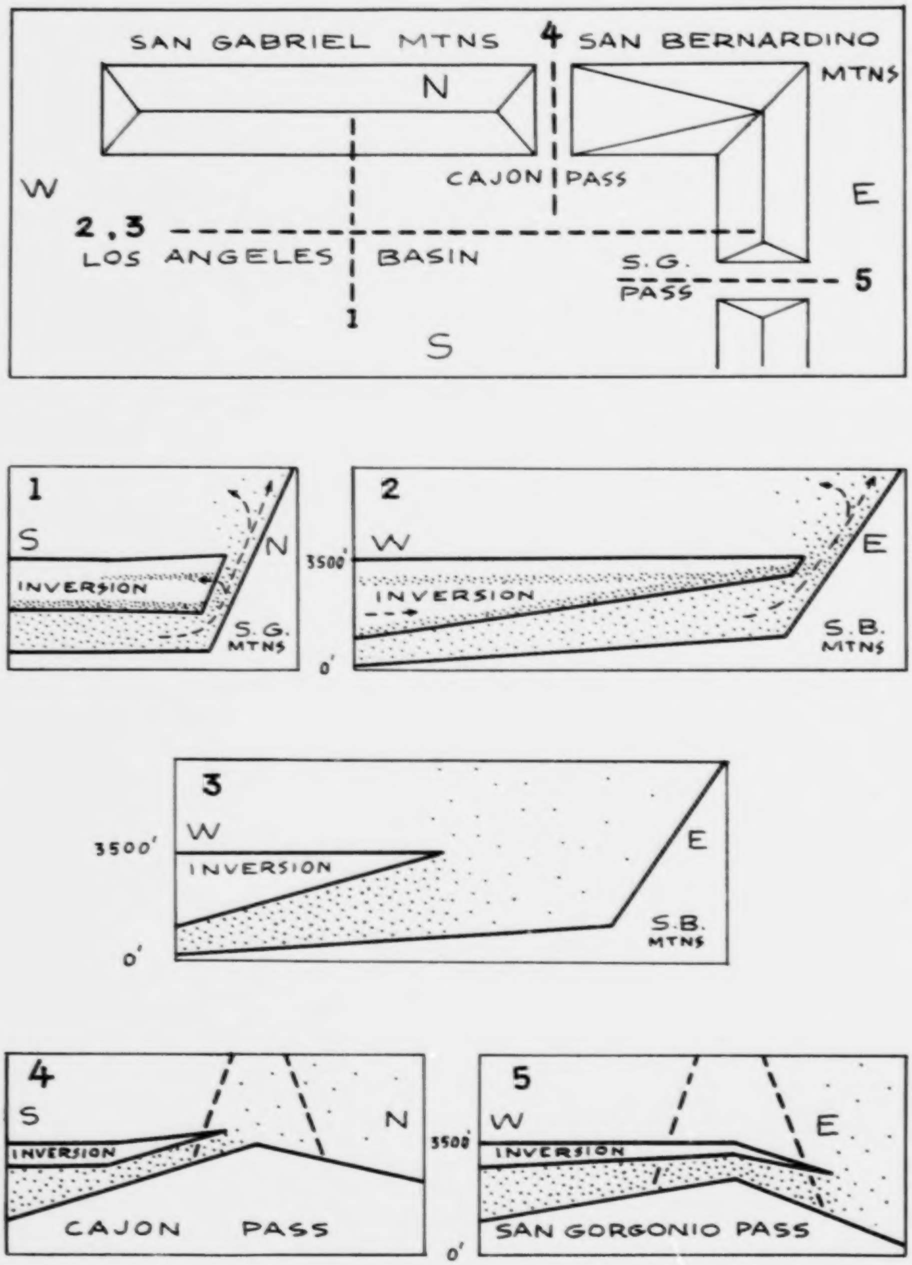
SAN GABRIEL MTNS
4
SAN BERNARDINO
MTNS
N
W
E
CAJON PASS
2,3
LOS ANGELES BASIN
S.G.
PASS
5
1
S
1
S
N
INVERSION
S.G.
MTNS
2
W
E
3500'
INVERSION
S.B.
MTNS
0'
3
W
3500'
INVERSION
E
S.B.
MTNS
0'
4
S
N
INVERSION
CAJON PASS
5
W
E
3500'
INVERSION
SAN GORGONIO PASS
0'

Figure D-9

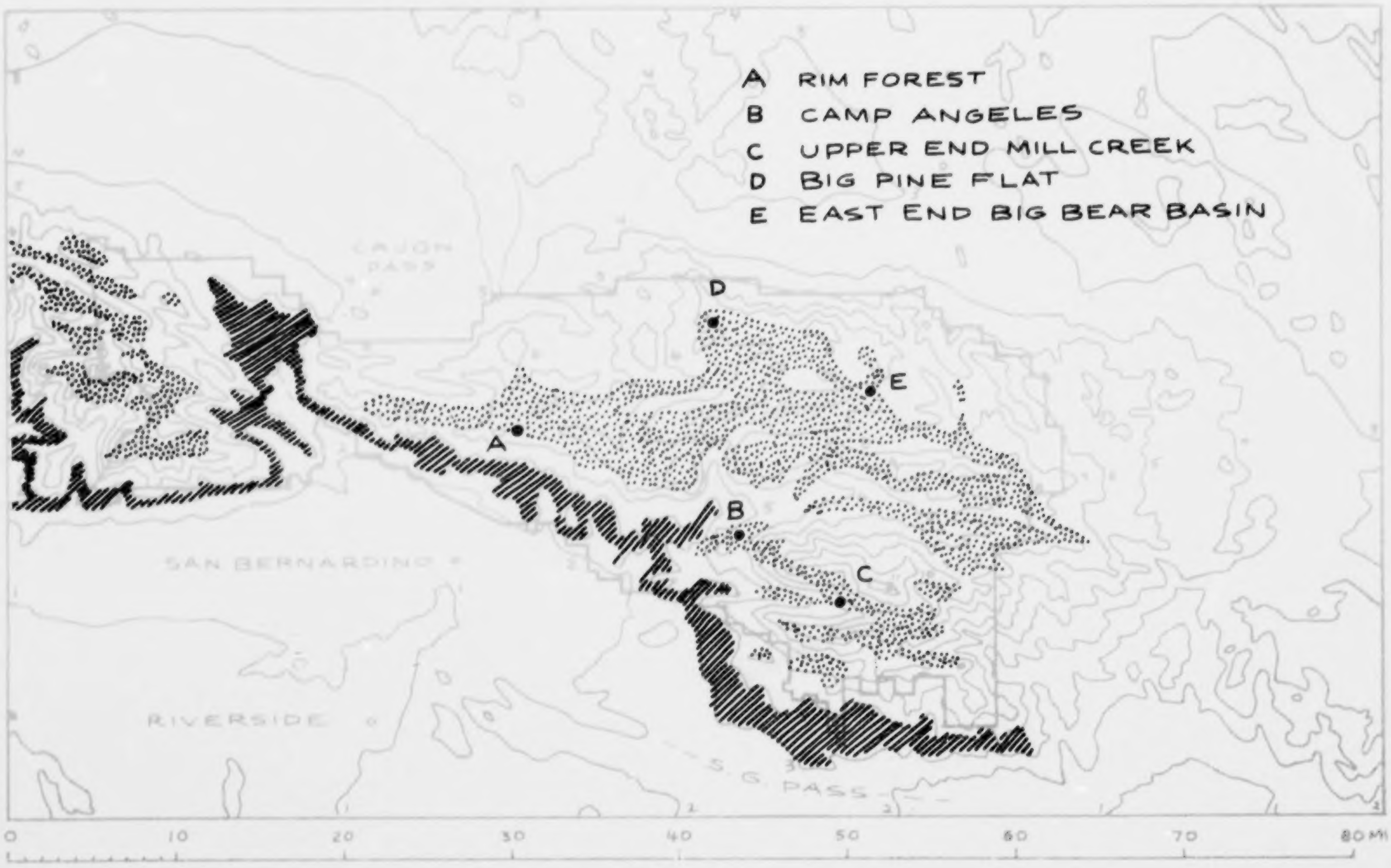
A RIM FOREST
B CAMP ANGELES
C UPPER END MILL CREEK
D BIG PINE FLAT
E EAST END BIG BEAR BASIN
CAJON PASS
SAN BERNARDINO
RIVERSIDE
S. G. PASS
A
B
C
D
E
0
10
20
30
40
50
60
70
80 MI

Figure D-10

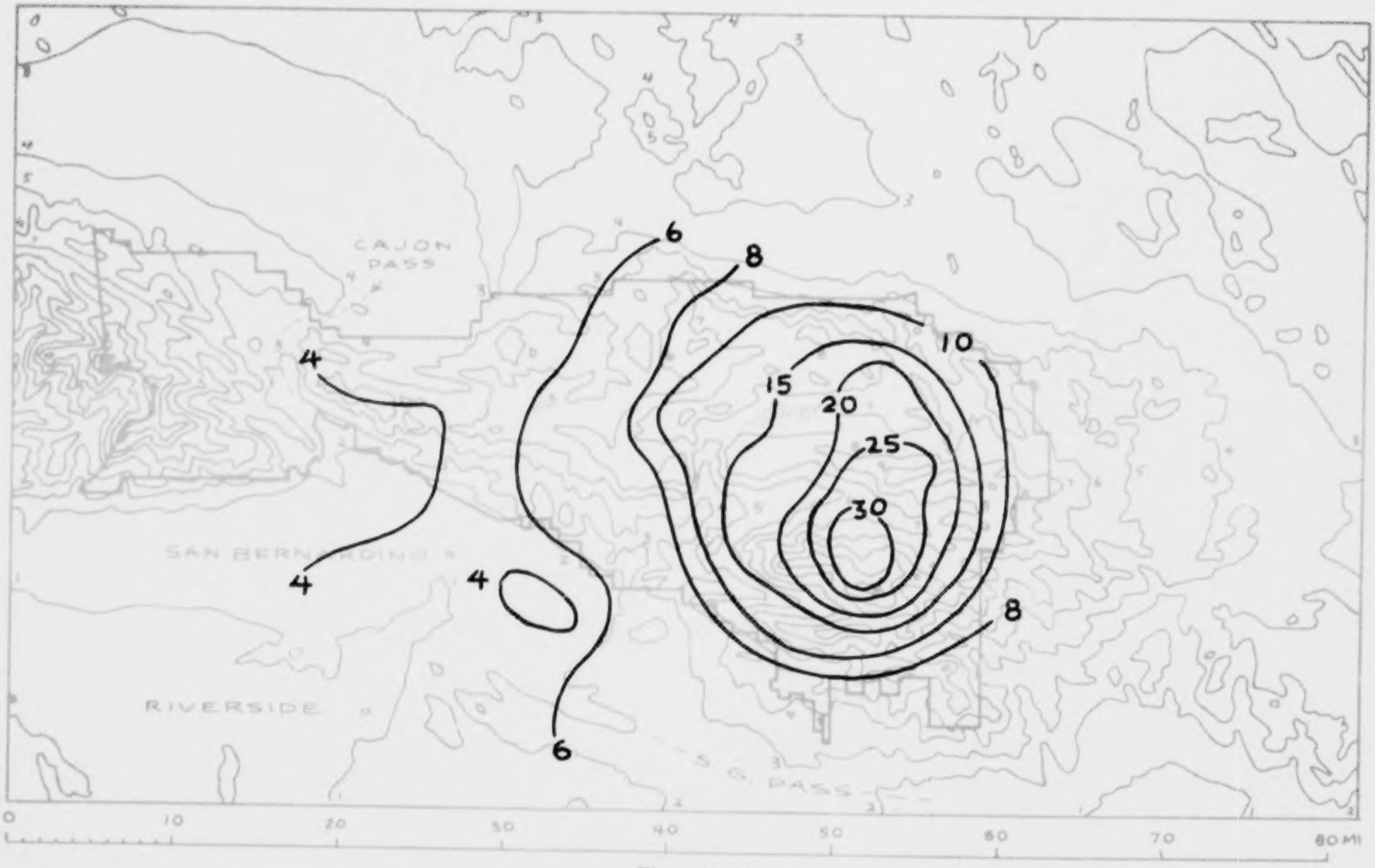
CAJON PASS
SAN BERNARDINO
RIVERSIDE
S. G. PASS
4
4
4
6
6
8
8
10
15
20
25
30
0
10
20
30
40
50
60
70
80 MI

Figure D-11

GEOLOGY, SOILS AND HYDROLOGY OF THE SAN BERNARDINO MOUNTAINS

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EROSION, SEDIMENTATION AND WATER QUALITY. 15

The San Bernardino Mountains are part of the Traverse Range Province that extends from west to east across parts of Santa Barbara, Ventura, Los Angeles, San Bernardino, and Riverside Counties, California (Bailey and Johns, 1954). They are situated between 116°30' and 117°30' West Longitude and 34°00' and 34°25' North Latitude. The San Bernardino National Forest in this area is bounded on the north by the Mojave Desert, the east by the Little San Bernardino Mountains, the south by the Upper Santa Ana Valley and Yucaipa-Beaumont Plains, and on the west by the San Gabriel Mountains.

The San Bernardino Mountains are characterized by deep, steep-walled canyons and altitudes ranging from 4,000 to over 11,000 feet (Figure E1). A subdued upland surface which is discontinuous is found in the Lake Arrowhead-Big Bear Lake region and is covered primarily by conifer forest. San Gorgonio Peak, the highest point in southern California (altitude 11,502 feet), is located in the eastern end of the San Bernardino Mountains along with many other prominent peaks and ridges.

GEOLOGY

A generalized geologic map of the San Bernardino Mountains is shown in Figure E2. This range was formed by uplift along the San Andreas fault zone on the south and along several steeply dipping reverse faults on the north.

The area is composed mainly of gneisses, schists, plutonic rocks, sediments, and recent alluvium. The Cactus granite formation (Miller, 1946), which is mainly a light-colored quartz monzonite of Mesozoic age, is exposed over a large portion of the mountain area, especially in the Lake Arrowhead region. This exposure is found primarily on the subdued upland surface. Metomorphosed sedimentary rocks of Paleozoic age are abundant in the area and numerous intrusions of metomorphosed rocks are found in both the Cactus formation and other plutonic bodies. Sedimentary rocks of Pliocene and Pleistocene age are also found in the area along with Recent alluvium.

The texture of the rocks found in this mountain area vary from fine textured volcanics to gravels which contain boulders several feet in diameter. Rocks which have been fractured and broken to a great extent are found in much of the mountain area, especially near faults and in fault zones. In some areas only normal jointing and fracturing are exhibited by the rocks. The presence or absence of fractures and joints is important to the hydrologic characteristics of the area in their effect on infiltration and runoff.

SOILS

Soils have formed in the San Bernardino Mountains through the influence of climate, relief, vegetation, parent materials and time. The climate varies from semi-arid to humid depending on altitude. The vegetation varies from chamise chaparral on the foothills to coniferous forest in the Lake Arrowhead regions. These factors are discussed in following sections.

As noted in the geology section, parent materials vary from Recent alluvium to weathering products of Pre-Cambrian rocks. Igneous, sedimentary and metamorphic rocks are present to serve as sources of parent material as well as alluvium derived from these sources. The types of parent material have influenced the texture, depth, and other properties of the soil found in this area.

Relief has been an important factor in soil formation in this area. Slopes vary from nearly level to nearly vertical. Soils found on steeply sloping land are generally shallow due to erosion processes during soil formation. Deeper soils are found on landscapes that are more stable such as on the relatively subdued upland surface around Lake Arrowhead.

The effects of climate and vegetation are impared on the parent materials. As parent materials are exposed to climate and vegetation for longer periods of time, soil formation processes result in deeper, finer textured soils. If relief is such that erosion would equal soil formation, time would have little effect on soil properties.

The various geologic materials in the San Bernardino Mountains have weathered by physical and chemical processes to form parent materials. These parent materials have been differentiated into soil profiles by the processes of additions, removals, transfers and transformations. Differences in the rates of these four processes have resulted in the formation of different soils.

Soil bodies which are similar in all properties (color, structure, depth, pH, etc.) except surface texture, are grouped together into a classification category, soil series. Soil types and soil phases which are subdivisions of soil series are used as mapping units when mapping soils within an area of interest.

No general mapping has been done in the San Bernardino Mountains; however, some mapping has been done by the U. S. Forest Service and the

Soil Conservation Service in small areas within the San Bernardino Mountains. The soil series that have been mapped in these areas are given in Table E1 along with some of their important properties. Other soil series which may occur in the Lake Arrowhead region are given in Table E2. Since little mapping has been done, few series have been described and correlated for this area. Some of the series names given in Table E1 are those which most nearly represent the observed soil characteristics.

Most of the soils mapped are coarse textured, well drained and have a low water holding capacity. These properties are primarily the result of relief and parent materials. Two soil series which may occur in the San Bernardino Mountains are Chawanakee and Shaver. These may represent somewhat a set of end-members of the soils found in this area. The former is a shallow soil and the latter a deep soil. The official description of these series is as follows:

Chawanakee Series

The Chawanakee series is a member of the loamy, mixed, mesic, shallow family of Dystric Xerochrepts. Typically, Chawanakee soils have grayish brown, medium acid, coarse sandy loam A horizons and very pale brown, medium acid B2 horizons overlying strongly weathered granitic bedrock.

Typifying Pedon: Chawanakee coarse sandy loam - forested.
(Colors are for dry soil unless otherwise stated.)

01 1-1/2-1/2" -- Grayish brown, dry, loose litter of bear clover, leaves and twigs with occasional pine needles.

02 1/2-0" -- Very dark grayish brown partly decomposed litter, weakly matted.

A1 0-6" -- Grayish brown (10YR 5/2) coarse sandy loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine granular structure; slightly hard, friable; many fine, small shrub roots; many small pores; medium acid (pH 5.7); diffuse smooth boundary. (3 to 6 inches thick)

B2 6-18" -- Very pale brown (10YR 7/3) coarse sandy loam, brown (10YR 5/3) moist; very weak fine granular structure; hard, friable, few small shrub roots; some continuous pores; medium acid (pH 5.7); abrupt irregular boundary. (8 to 30 inches thick)

C 18-32" -- Pale brown disintegrated and partly decomposed parent rock; mineral grains retain original orientation; thin discontinuous reddish brown (5YR 4/4 and 4/6, dry) clay films on some mineral grains and partially fills some spaces between grains, diminishing with depth, disappearing below 30 inches; grades to unweathered rock at undetermined depth.

Shaver Series

The Shaver series is a member of a coarse-loamy, mixed, mesic family of Pachic Ultic Haploxerolls. The soils have dark grayish brown to grayish brown coarse sandy loam A1 horizons, brown coarse sandy loam AC horizons, pale brown coarse sandy loam upper C horizons which overlie strongly weathered acid igneous rock.

Typifying Pedon: Shaver coarse sandy loam - forested
(Colors for dry conditions unless otherwise noted)

O11 -- 3-2" -- Dried litter of white fir and sugar pine needles, some twigs.

O12 -- 2.0" -- Partially decomposed litter; abundant white fungal mycelia; rests abruptly on:

A11 -- 0.2" -- Dark grayish brown (10YR 4/2) coarse sandy loam, very dark brown (10YR 2/2) moist; strong fine crumb structure; soft, very friable; abundant fine roots; many fine interstitial pores; slightly acid (pH 6.5); abrupt wavy boundary. (2 to 9 inches thick)

A12 -- 2-5" -- Grayish brown (10YR 5/2) coarse sandy loam, dark brown (10YR 3/3) moist; moderate fine crumb structure; soft, very friable; abundant fine, plentiful medium, few coarse roots; many fine interstitial pores; slightly acid (pH 6.3); clear wavy boundary. (3 to 14 inches thick)

AC -- 5-33" -- Brown (10YR 5/3) coarse sandy loam, dark brown (10YR 3/3) moist; weak fine crumb structure; soft, very friable; abundant fine, plentiful medium and coarse roots, very few large roots; many fine interstitial pores; slightly acid (pH 6.2); abrupt wavy boundary (12 to 54 inches thick)

C1 -- 33-73" -- Pale brown (10YR 6/3) coarse sandy loam, dark brown (10YR 4/3) moist; massive; slightly hard, very friable, very slightly sticky; many fine, medium and coarse roots, very few large roots; common fine and medium tubular pores, many fine interstitial pores; medium acid (pH 5.9); abrupt irregular boundary. (7 to 40 inches thick)

C2 -- 73"+ -- Light gray, strongly weathered quartz diorite; original rock fabric clearly visible in place; easily excavated and crushes readily to a coarse sand; porous; occasional large tree roots; many feet to unweathered rock (R).

A property associated with many southern California soils of interest to any ecology study is water repellency. Water repellency will have an effect on infiltration and runoff characteristics of any soil that is water repellent. The water repellency in some soils is intensified by heat such as a forest fire. Debano (1969) found the water repellency in a 2 to 4 inch depth increased in a burned area compared to an unburned area.

Water repellent soils are present in the San Bernardino Mountains (Holzhey, 1969). Some areas show seasonal repellency while others are water repellent year-around. The various degrees of water repellency appear to be related to vegetation, parent material and topography; however, no specific relationship has been found.

DRAINAGE BASINS AND RUNOFF

The creeks and rivers for the San Bernardino Mountains are indicated in Figure 3. The northern slopes of the study area are drained by Deep Creek and the West Fork of the Mojave River along with other minor tributaries and intermittent streams. The creeks and rivers on the northern slopes drain into the Mojave River. The combined flow of the West Fork of the Mojave River and Deep Creek discharges an annual average of 84,500 acre feet onto the adjacent valley floor. All of this runoff, except for flood periods, becomes a recharge to ground water storage in the Mojave Desert. The geology of the northern slopes is of principally granitic origin (Figure 2E). Geologic parent materials of this nature are generally the least water absorptive and retentive mantle rock and because of this the northern slopes which drain into the Mojave River have high winter flood runoff and low summer delayed runoff. Storm surface runoff occurs in the San Bernardino Mountains only during a shower of unusual intensity. Due to the characteristics of the mantle rock this runoff is caused by temporary ground water storage. Relative to runoff characteristics mantle rock can be placed in three rather broad categories: (a) least absorptive and retentive mantle rock having maximum flood runoff and minimum summer delayed runoff; (b) moderately absorptive and retentive rock having moderate flood and summer delayed runoff; and (c) most absorptive and retentive mantle rock having minimum flood runoff and maximum summer delayed runoff. For the northern slopes draining into the Mojave Desert about 80%, 5%, and 15% of the mantle rocks fall into the categories of least absorptive and retentive, moderately absorptive and retentive, and most absorptive and retentive, respectively (Troxell, 1954).

The southern slopes of the study area are drained by the Santa Ana River and its tributaries (Figure E3). The more important creeks on the southern slopes almost immediately south of Lake Arrowhead include Plunge Creek, City Creek, Strawberry Creek, Waterman Canyon Creek, and Warm Creek. Approximately 30% of this region contains mantle rock with least absorptive and retentive properties, while 60% and 10% of the mantle rocks in the region can be classified as moderately absorptive and retentive, and most absorptive and retentive, respectively. The Santa Ana River and Mill Creek drain the southern slopes southeast of the study area. Mantle rock for this region can be categorized as about 20% least absorptive and retentive, 30% moderately absorptive and retentive, and 50% most absorptive and retentive. The southern slopes west of the study area are drained principally by Lone Pine Creek and Lytle Creek. Mantle rock in this region is approximately 80% most absorptive and retentive and 15% moderately absorptive and retentive. In summary, mantle rock on the northern slopes of the San Bernardino Mountains provide the least conducive conditions for ground water runoff and storage, while those to the west of the study area on the southern slopes provide the conditions conducive to the maximum ground water runoff and storage.

EROSION, SEDIMENTATION AND WATER QUALITY

There are very few data available on erosion, sedimentation, and water quality for the study area. The U. S. Forest Service[1] are currently in the early stages of setting up a water quality program for the San Bernardino National Forest. Parameters to be measured include flow, temperature, turbidity, dissolved oxygen, phosphates, total hardness, total dissolved solids, bacteria, sedimentation and erosion.

Acute erosion problems commonly occur following forest fires. An example of this is the Plunge Creek drainage (Figure E3) which is somewhat similar in geology and soils to the Deep Creek area. Sediment measurements for the first year after a wildfire showed debris yields up to 108,500 cubic yards per square mile. Debris gradually decreased to 3,600 cubic yards per square mile ten years after the burn.[1] Removal of vegetation by logging, housing developments, roads, and any other means may increase stream flow, erosion, and sedimentation. Drastic reduction in timber stands caused by air pollution would, in effect, produce results similar to forest fires. Since reductions caused by air pollution would be gradual, their effects should not be as acute as those associated with fire.

Changes which may occur in soil properties would be restricted to the surface horizons. If the canopy were to be reduced by forest thinning, this would affect both the amounts of organic matter accumulated in the soil surface and the rate at which it would be microbially decomposed. The soil surface would intercept more heat thereby resulting in a greater degree of decomposition of the organic materials. Coniferous vegetation produces an acidic environment. Under conditions where the amounts deposited on soils were reduced the chemical weathering of the soil materials would be retarded. On the steep slopes if vegetation were drastically reduced, seasonal erosion of surface deposited materials would alter the normal soil forming processes.

---

[1] Private communication, U. S. Forest Service.

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Table E1. Soil series which have been mapped in the San Bernardino Mountains

Soil Series	Surface texture	Slope on which series occurs %	Parent material	Natural drainage	Runoff	Erosion hazard	Effective depth in.	Available water capacity
Ahwahnee*	coarse sandy loam	5-50	decomposed granodiorite	well	medium to rapid	moderate to high	24-40	medium to low
Auberry*	coarse sandy loam	15-30	weathered granite	well	medium to rapid	moderate to high	40-60	medium
Bancas*	fine sandy loam	15-50	weathered granite	well	medium to rapid	high	30-40	medium
Behemotoch*	gravelly loam	15-75	schist	well	medium to very rapid	high to very high	30-40	low
Chiquito*	very gravelly sand	20-50	weathered granodiorite	excessive	medium to rapid	moderate	20-30	low
Cieneba*	rocky sandy loam	9-50	weathered granite	well	medium to very rapid	moderate to high	10-20	low
Godde*	very gravelly loam	> 70	weathered schist	well	very rapid	very high	10-20	very low
La Posta	loamy coarse sand	5-30	decomposed granodiorite	excessive	medium to rapid	high	20-36	low
Mottsville	stony loamy sand	9-15	granitic alluvium	excessive	slow	slight	60+	low
Oak Glen	sandy loam	0-30	granitic alluvium	well1/	very slow to medium	slight	60+	medium to high
Soboba*	cobbly loamy sand	2-9	granitic alluvium	excessive	slow	slight	60+	low
Stoner*	cobbly loamy sand	15-30	weathered granodiorite	well	medium to rapid	moderate	24-48	medium
Tollhouse	cobbly sandy loam	5-50	weathered granodiorite	well	medium to rapid	slight to high	10-20	low

* Series indicated most nearly corresponds with the observed field characteristics.

1/ Seasonally wet.

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Table E2. Soil series which may occur in the San Bernardino Mountains

Soil Series	Surface texture	Slope on which series occurs %	Parent material	Natural drainage	Runoff	Erosion hazard	Effective depth in.	Available water capacity
Bull Trail	sandy loam	9-15	granitic alluvium	well	medium	moderate	60+	low
Chawanakee	sandy loam	10-30	weathered granite	well	medium to rapid	moderate to high	10-40	low
Coarsegold	loam	10-30	weathered mica schist	well	medium to rapid	moderate	20-40	medium to high
Crafton	sandy loam	20-50	micaceous schist	well	medium to rapid	moderate	20-40	medium
Crouch	sandy loam	10-30	weathered granite	well	medium to rapid	moderate	24+	well
Shaver	sandy loam	10-30	weathered granite	well	slow to medium	moderate	60+	low
Sheephead	fine sandy loam	10-30	micaceous schist	well	medium to rapid	moderate	10-20	low

Figure Legends

Fig.	
E1	Topographic map of the San Bernardino Mountains. Contour interval is 500 ft.
E2	Geology map of the San Bernardino Mountains.
E3	Drainage basins in the San Bernardino Mountains

E-16

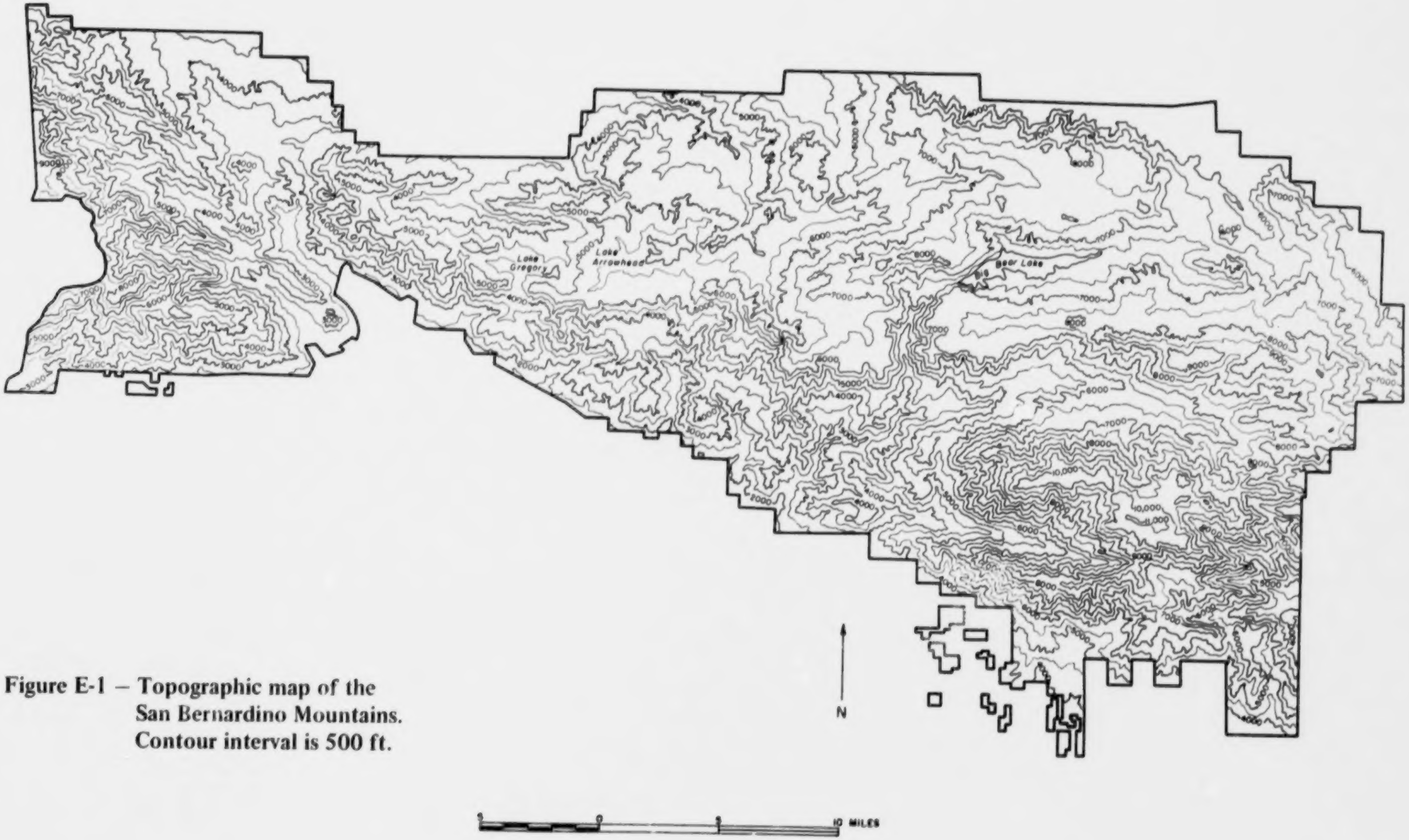
Lake Gregory
Lake Arrowhead
Big Bear Lake
N
5
0
5
10 MILES

Figure E-1 – Topographic map of the San Bernardino Mountains. Contour interval is 500 ft.

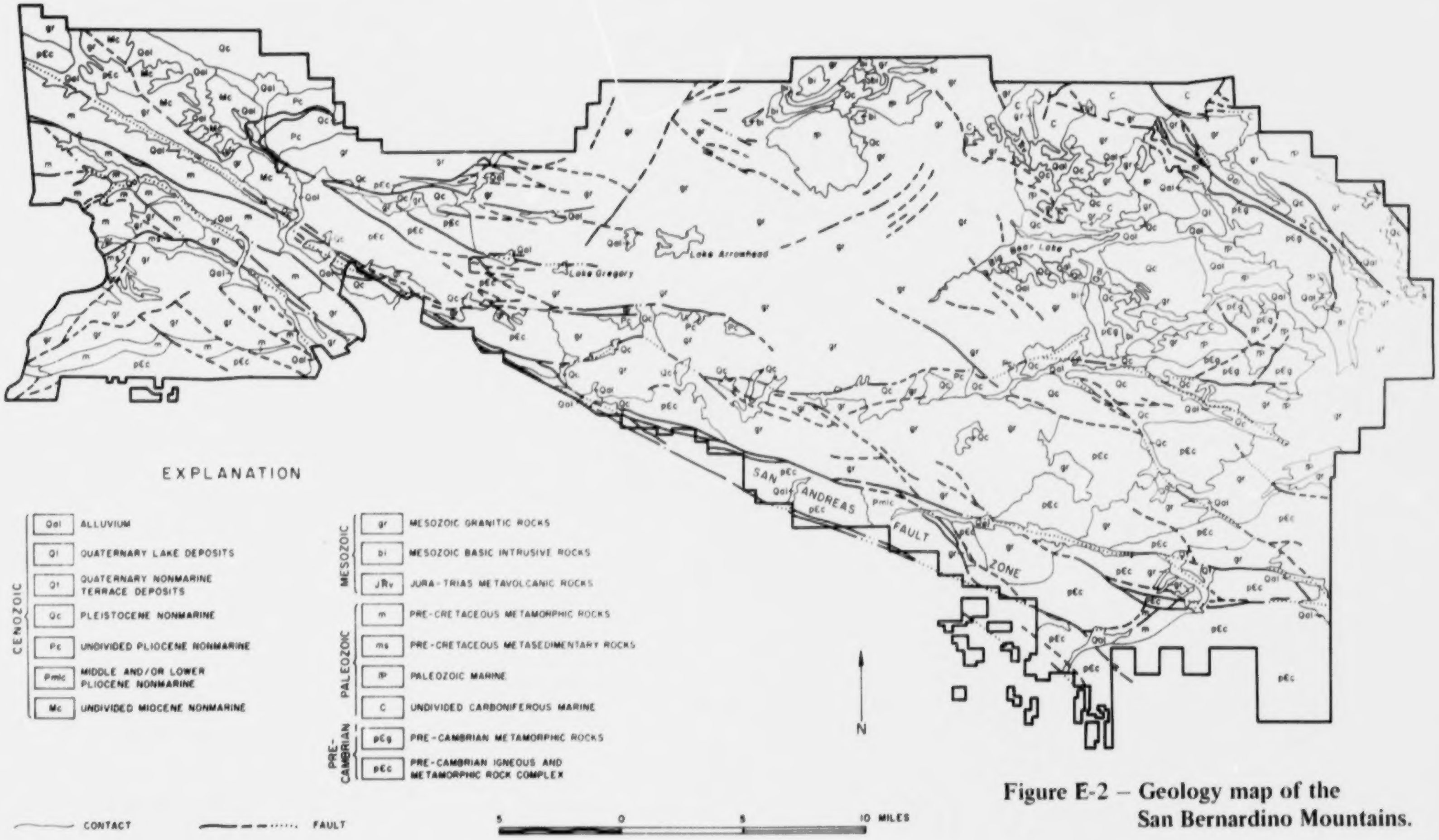
Lake Arrowhead
Lake Gregory
Bear Lake
SAN ANDREAS FAULT ZONE
N
EXPLANATION
CENOZOIC
Qal ALLUVIUM
Ql QUATERNARY LAKE DEPOSITS
Qt QUATERNARY NONMARINE TERRACE DEPOSITS
Qc PLEISTOCENE NONMARINE
Pc UNDIVIDED PLIOCENE NONMARINE
Pmlc MIDDLE AND/OR LOWER PLIOCENE NONMARINE
Mc UNDIVIDED MIOCENE NONMARINE
MESOZOIC
gr MESOZOIC GRANITIC ROCKS
bi MESOZOIC BASIC INTRUSIVE ROCKS
JRv JURA-TRIAS METAVOLCANIC ROCKS
PALEOZOIC
m PRE-CRETACEOUS METAMORPHIC ROCKS
ms PRE-CRETACEOUS METASEDIMENTARY ROCKS
P PALEOZOIC MARINE
C UNDIVIDED CARBONIFEROUS MARINE
PRE-CAMBRIAN
pЄg PRE-CAMBRIAN METAMORPHIC ROCKS
pЄc PRE-CAMBRIAN IGNEOUS AND METAMORPHIC ROCK COMPLEX
CONTACT
FAULT
5
0
5
10 MILES

Figure E-2 – Geology map of the San Bernardino Mountains.

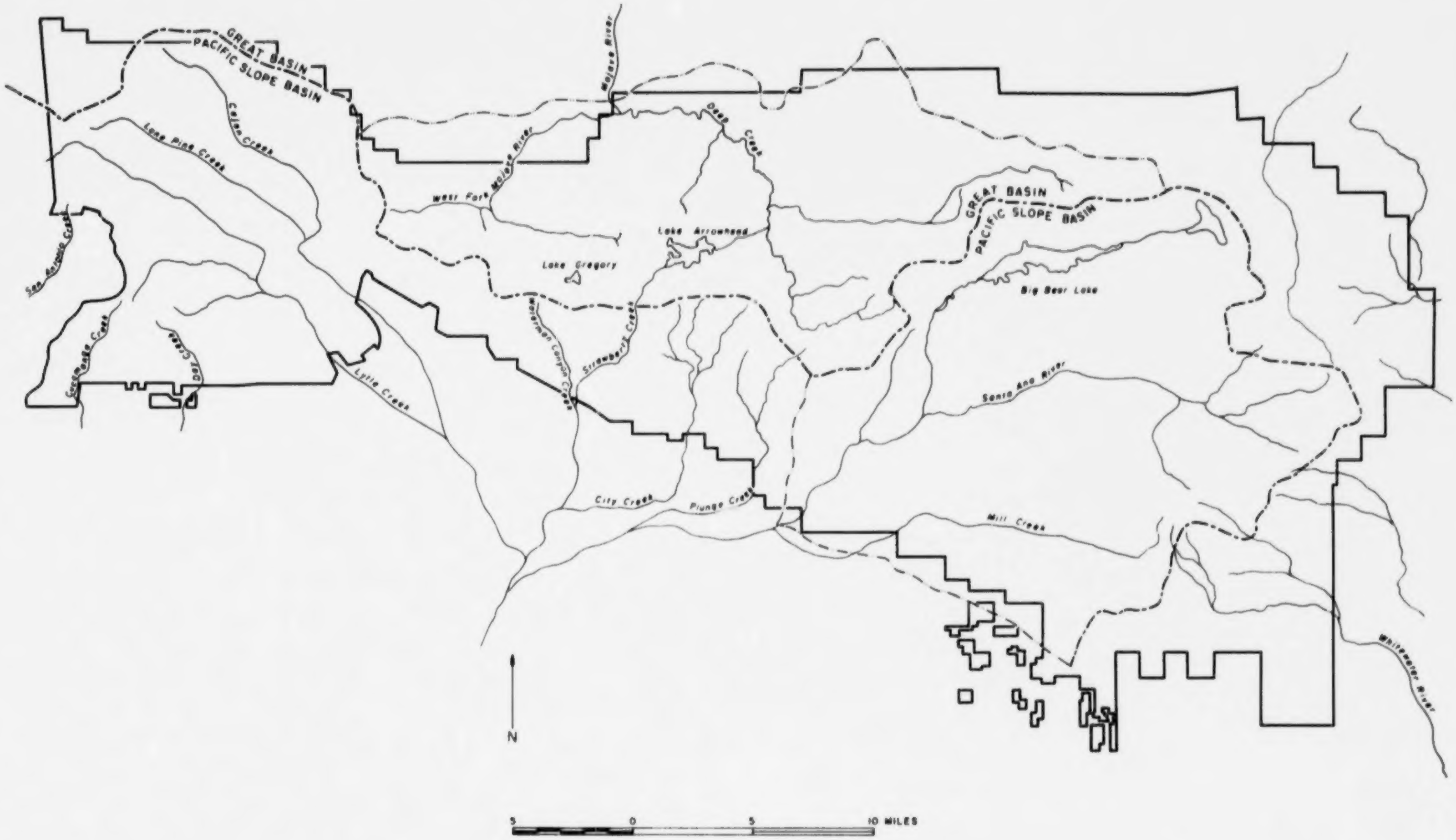
GREAT BASIN
PACIFIC SLOPE BASIN
Cajon Creek
Lone Pine Creek
San Antonio Creek
Cucamonga Creek
Day Creek
Lytle Creek
West Fork
Mojave River
Mojave River
Deep Creek
Lake Gregory
Lake Arrowhead
Waterman Canyon Creek
Strawberry Creek
City Creek
Plunge Creek
GREAT BASIN
PACIFIC SLOPE BASIN
Big Bear Lake
Santa Ana River
Mill Creek
Whitewater River
N
5
0
5
10 MILES

Figure E-3 Drainage basin in the San Bernardino Mountains.

Sociology Committee Report

History and Suggested Protocol
for
Environmental Protection Agency

Study of the Impact of Oxidant Air Pollution on the Mixed Conifer Forest Ecosystem

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I. INTRODUCTION

This section of the report presents results of the search for historical and demographic data and information on the utilization of the Lake Arrowhead region by the human population, along with some background material suggesting possible effects of oxidant air pollution upon the human population. In addition, a brief description of a frame of reference for future studies of the effects of oxidant air pollution upon man in the Lake Arrowhead region is given. Beyond describing the historical background, the human population and its use of the Lake Arrowhead habitat, and the possible effects of oxidant air pollution on man, this report briefly suggests a frame of reference for the long term study of oxidant air pollution and begins to outline methods and techniques that may be used in areas other than Lake Arrowhead to more effectively study the impact of air pollution upon man.

A large number of social scientists, in a variety of disciplines, have expressed interest in future research endeavors to be centered in the Lake Arrowhead region; the following persons made contributions to the compilation of data and writing of the Social sciences section contained herein.

Edgar W. Butler, Coordinator, Sociology, U.C.R.
Sheldon Bockman, Sociology, U.C.R.
John F. Freeman, Sociology, U.C.R.
Charles E. Starnes, Sociology, U.C.R.
Joanne Hancock, R.A., Sociology, U.C.R.
David McElroy, R.A., Sociology, U.C.R.

II. HISTORICAL BACKGROUND ON LAKE ARROWHEAD

The introduction of human society to the San Bernardino Mountains, with the exception of small, scattered Indian settlements, probably began in the Spring of 1852 when the first roadway was cleared to the top of the mountains. Amasa Lyman, Bishop Crosby, and Charles Crisman organized a party of men from the Mormon fort in San Bernardino to begin work on a steep, narrow roadway which opened the mountains and valuable timberland to them. The year of 1852 was a busy one in the mountains, for in the Fall of that year a United States deputy surveyor climbed to the highest peak and took bearings for the first true east-and-west map line in Southern California.

Ten years after Mormon settlers from San Bernardino set up several small logging operations in the mountains, lumbering had become a major enterprise. Most settlers were content with farming the land in the valley below, but numerous pioneers established small land holdings in the mountains. However, no large settlements sprang up in the mountains until the 1920's. Many species of wildlife roamed the mountains in considerable numbers, but the human population settled itself in the logging camps or in the valley below. Gold and other minerals were discovered in the mountains and many small placer mines and claims were established with such pictureqe names as Sitting Bull, Blowout, Lone Star, Diablo, and Upset.

Settlement took place in Bear Valley and further west in Grass Valley and Little Bear Valley. Little Bear Valley is of particular concern to this study because the Little Bear meadow became the site of Lake Arrowhead. The Talmadge Mill was located near the site where the Lake Arrowhead "Village" was later established.

The history of Lake Arrowhead as a "lake" began in 1891 when the Arrowhead Reservoir Company incorporated and built the first passable road into the mountains, thus making them more accessible. Substantial organized settlement in the mountains began with the building of small, private lodges such as the "Squirrel Inn" and by 1895 tourists were treking up the Arrowhead toll road to visit the primitive yet comfortable retreats. The mountains were "officially" conquered on June 30, 1900 when a Locomobile made a test run up the narrow winding road to Bear Valley, across the mountains, and down the Arrowhead toll road. The Arrowhead Reservoir Company had been in operation for thirteen years when, in 1904, it let the official contract to build the cement corewall for the little Bear Valley reservoir. Such a major construction project was a great undertaking given the primitive roads and the difficult accessibility to the site.

Accessibility to the mountains was always a problem. Transportation on the roads was hazardous because of steep grades and switchbacks which often proved fatal to loggers bringing lumber down from the mountains. Tourists visiting the mountains with increasing frequency found transportation lacking because automobiles were not permitted on the toll road. A solution to the transportation problem was begun when the Pacific Electric Railway laid track from San Bernardino to the Arrowhead Hot Springs Hotel in Waterman Canyon at the base of the mountains. In 1908, the Arrowhead Road was given to the County of San Bernardino and automobilists began to drive cars up the County Road in Waterman Canyon. Within a year the road was open to automobiles, thus creating a booming tourist business.

The permanent residents in the mountains were hearty, rowdy, pioneering people who sometimes backed up their words with guns and violence. Logging as a destructive element in the mountains was impeded when the mountains became a national forest and rangers enforced some order on the mountain society. In contrast to tough permanent residents, summer tourists who visited the area were wealthy, upper-class people who could afford to be dilletante nature lovers. The tourist society was a gay, carefree crowd given to elegant balls in outdoor pavillons, potato and marshmallow roasts, watermelon feasts, and campfire sings. Catering to the tourist trade, like the logging and mining industries, had become a paying enterprise in the mountains.

In 1920, the Lake Arrowhead Company purchased the properties of the Arrowhead Reservoir and Power Company which was centered in Little Bear Valley. A spokeman for the new company said that the Arrowhead Company planned to create a lake in the west fork of the Mojave and send water to some of the desert-side irrigation districts; to raise the Little Bear Dam thirty-one feet. . . and change its name and that of the lake formed to "Lake Arrowhead". Within two years the Lake Arrowhead project had been mapped out in minute detail, planning the development of every foot of the five-mile shoreline. The directors of the company met with the Rim of the World Association and attempted to get better roads and stage service to Lake Arrowhead.

In the middle of April, the Arrowhead Lake Company began putting its development plans into effect. A large group of men leveled a terrace for the business section at the west end of the lake near the Little Bear Resort buildings which were being demolished. In the pine woods across the cove from the village, housekeeping cabins were built. At Orchard Bay a pay auto-camp to hold a thousand cars for fishermen was built. The grand opening of the first facilities, including a hotel, village stage depot, shops, market, art shop, drug store, dance pavilion, and a gas station, was set for June.

The opening of the new Lake Arrowhead Company brought dignitaries from all over Southern California and two hundred and fifty newspapermen and women. All were impressed with the orderly growth, the unifying architecture, the combination of the works of Nature with artistic and beautiful works of man. Transportation was still somewhat of a problem even during the summer. The Motor Transit Company which offered two round trips a day to Lake Arrowhead was notorious for lateness, discomfort, speed at viewpoints, overloading, and danger, since a car tumbled off a soft shoulder at a steep grade. The Company held a $5,000 contract for delivery of the U.S. mail as well.

Lake Arrowhead became a thriving settlement with 44 resorts, all supplied with electricity. The services of a doctor, minister and local court judge also were available. The first permanent social organizations were started--a masonic lodge and a women's club. In 1923 the Pacific Telephone Company completed a single line through to Lake Arrowhead, enabling the mountain community to communicate with the outside world. The Federal government appropriated $75,000 to the National Forest-Highway program for construction of a good road to the top of the mountain.

The Lake Arrowhead complex offered additional services to its residents with the opening of a branch office of the Pacific Southwest Savings and Trust Company.

Spiritual needs were attended to by Catholic priests who held mass in the hall across from the Lake Arrowhead Post Office. American Legion members residing in Lake Arrowhead received a 14 acre government plot on which to place a building. The North Shore subdivision was being offered, with such notables as an heiress of the National Biscuit Company purchasing land. Other retreats were established by movie stars Buster Crabbe, Gene Lockhart, J. Carrol Nash, and Myrna Loy. The number of permanent year-round residents was increasing and in 1924 the first school--Lake Arrowhead Elementary School --was established in a small, wood frame building for the 14 children of permanent residents. The area became increasingly popular as a resort settlement and there were upwards of 200 resorts there in 1924. With the increased number of residents and visitors, fires and environmental pollution appeared, as well as a decline in wildlife.

Growth continued during the next few decades and today the area contains many large homes, mountain retreats, and a larger resident population and millions of visitors.

III. THE HUMAN POPULATION AND ITS USE OF THE LAKE ARROWHEAD HABITAT

Currently, the forest region has a human population highly variable in density and spatial distribution, and the population fluctuates by season, month, day of the week, and snowfall. Several different and relevant human populations utilize the Lake Arrowhead region, thus any evaluation of land use requires information on the following: (1) permanent residents, (2) owners who intermittently utilize their property as summer and recreational facilities for themselves, relatives, and friends, and (3) "visitors"--the transient population. Population data pertaining to the permanent residents and intermittent users can be obtained from the United States Census and are discussed in more detail below. Estimates only are available for the visitor population.

Assuming that residential growth in the San Bernardino National Forest will be minimal and that zoning will prohibit multiple family housing units or high-rise construction in the Lake Arrowhead region, the actual population growth potential of Lake Arrowhead is severely limited by geographical constraints. However, recent expansion of one of the major access highways to four lanes decreased highway congestion and made accessibility easier for an increased number of visitors. Other major routes may be widened thus providing easy accessibility to Lake Arrowhead for virtually all Southern California residents. While the permanent population growth may have upper limits, this easy accessibility, coupled with higher per capita incomes, may result in an ever increasing visitor use of picnic grounds, campgrounds, and other recreational facilities, leading to increased locally produced air pollution and despoilation of the environment.

Lake Arrowhead is located in San Bernardino County, one of the eleven counties constituting Southern California. Southern California is expected to have a population of eighteen million persons by 1980. Of the 684,072 people enumerated in San Bernardino County in the 1970 U.S. Census of Population and Housing, 180,000 of them were added during the previous decade. San Bernardino County contains 20,160 square miles and is highly diverse in its social, economic, and topographic composition. The vast majority of the population (all but 138,000) reside in the valley south of the national forest boundary. In addition to the local resident population, the San Bernardino National Forest receives an estimated eight million visitors a year.

A precise description, beyond sheer numbers, of the population in the immediate Lake Arrowhead environments is extremely difficult because each agency defines boundaries somewhat differently. One boundary, San Bernardino County Planning District 16, includes the Lake Arrowhead census tract as well as two others. In 1970, this planning district contained a population of 18,267. The population is expected to grow to 25,000 by 1980 and to over 31,000 by 1990. Census Tract 101--Lake Arrowhead--had a population of 2,343, in 1950; 4,247 by 1960; and a population of 10,437 in 1970. During the past decade the resident population has been increasing at a faster pace than dwelling units, suggesting that an increasing proportion of people are utilizing their property at Lake Arrowhead as a full time, permanent place of residence. Enumeration district data (E.D's 210-223) indicate that the immediate Lake Arrowhead habitat had a population of 3,031 in 1970. Using a slightly different population base of 2,672 (less two of the above E.D.'s), in 1970 the resident population was 98.4% white, with a median age of 31.2 years. Almost 63% of the dwelling units were vacant at the time of the 1970 census, 25.4% were occupied by owners, and 11.8% were occupied by renters. The vacancy rate, of course, reflects the important recreational facet of the Lake Arrowhead region and part-time use by people from Los Angeles, Orange, Riverside, San Bernardino Counties and elsewhere. Over 90% of the dwellings are single-unit structures. Median value of owner occupied units at the time of the census was $31,250; median rent was $131 per month.

Land use within the immediate vicinity of the Lake is primarily residential except for the "Village" which contains commercial, shopping, and business areas, a small lake adjacent to the country club, a riding club, the University of California Conference Center, and a few public facilities, such as schools. The Lake Arrowhead population concentration is virtually surrounded by the San Bernardino National Forest.

Because of the small permanent population living in the mountain region, most of the oxidant air pollution is not locally produced, but rather comes from population concentrations and industry in Los Angeles, Orange, and Riverside Counties, and from the valley population of San Bernardino County. Therefore, although the population growth in the mountain region is limited by the amount of land now available for private use, the air pollution supply is virtually unlimited. As the population of the Los Angeles basin increases and as industry, automobiles, and other sources of pollution increase, it is expected that the air pollution problem will become more severe in the Lake Arrowhead region.

One major use of the mountain region, of course, is recreation. People tend to use recreational facilities without regard to jurisdictional boundaries; therefore, the Lake Arrowhead recreational area has a potential population reservoir, throughout Southern California, of eighteen million persons to draw upon. This vast population reservoir generates recreational demands ranging from the most urban to the most rustic, including picnic grounds, riding and hiking trails, scenic drives and parkways, and skiing, fishing, hunting, and boating areas (SCAG, September, 1970). The region embraces the San Bernardino National Forest which is the largest national forest in Southern California. About 3/4's of the acreage of the Lake Arrowhead region is included in the

National Forest, which drew an estimated 8 million visitors last year. These visitors included those who stayed one day or less as well as campers and vacationers who stayed several days.

As indicated on Figure G-1, virtually all of the major recreational facilities in San Bernardino County (excluding only the Colorado River area and the Prado Basin) are concentrated in the San Bernardino Forest--Lake Arrowhead vicinity. Silverwood Lake in the region is in process of being fully developed as a multiple-purpose recreational center and will very shortly substantially increase the number of visitors to the region. In addition, Holcomb Valley is an underdeveloped section with high potential recreation usage.

Precise data on the specific use of main highways are available from the California State Department of Highways. Utilization of public campsites and picnic grounds, Natural Preserves, etc., are available from the United States National Forest Service, San Bernardino, California, and Washington, D.C. When more time and resources are available these data sources will allow a determination of the total in-and-out flow of traffic into the region. Currently, we do not have an estimate of the impact of air pollution of the human population of the Lake Arrowhead region nor of the effect of air pollution and the human population on the ecological balance of the Lake Arrowhead environment.

IV. POSSIBLE EFFECTS OF OXIDANT AIR POLLUTION ON MAN

In this section we discuss the following: (A) the perceptual awareness of air pollution, (B) the possible impact of air pollution on human behavior, (C) the organization of the human population, (D) the organizations that people may belong to, (E) the economic costs of air pollution, and (F) its health and mortality implications.

A. Perceptual Awareness. Studying the perceptual awareness of air pollution assumes that humans are the creators of the condition, the measurers of the problem, and the sources of the solution. The fact that pollution exists and is relative to human perception carries with it two important considerations. The first is to what degree the conditions are tolerable; the second is the extent that toleration varies by different population segments. Differential perceptual awareness may lead to varying behavioral and organizational responses by human beings (Molotch, forthcoming). Perception, or lack thereof, of air pollution may be considered exclusive of its involuntary effects upon individuals. In fact, literature suggests that air pollution has its most adverse effects on older persons, yet it is older persons who are the least perceptive of air pollution. Only if air pollution is perceived as a problem, will corrective action be taken, because it is probable that only those persons who perceive air pollution as a serious problem are likely to attempt to do anything about it. Further, it is probably only an aware and awakened public that will support effective control programs.

Previous studies of the perceptual awareness of air pollution have focused primarily on the following:

(1) Perception of the nature and extent of air pollution as a problem.
(2) Where knowledge about air pollution is obtained.
(3) What are the attitudes about the air pollution problem.
(4) What, if anything, should be done about air pollution.

(5) What programatic elements persons will accept and support in efforts by local, state, and federal governments to overcome the air pollution problem.

(6) How accurately individuals perceive air pollution.

(7) Whether perception of the air pollution problem galvanizes the individual into behavioral responses.

(8) What are the perceived causes of air pollution.

No data exists that describes the level of awareness of air pollution by the region's population. Casual discussions with residents and newspaper articles suggest a polarity of responses. Many residents are highly disturbed by the air pollution and want to something about it. Other residents deny its very existence and, obviously, since the problem does not exist for them, nothing should be done about it from their point of view.

B. Behavior. While knowledge about and perception of air pollution are important areas of concern, it is conceivable that air pollution may effect human behavior regardless of whether or not it is perceived. One obvious response to it if it is perceived is to avoid it by moving to another pollution free location (Butler, et al, 1972). Air pollution may restrict other behavior such as the amount of physical exertion that is deemed desirable by authorities (i.e., in schools physical education may be terminated if air pollution reaches a specified level, a level which appears to vary by school district in the Los Angeles basin). Furthermore, air pollution may restrict breathing, result in eye and nose irritation or make the individual feel so poorly that he does not want to work or become involved in physical activities.

Under severe air pollution conditions, visibility may be so markedly reduced that normal community activities must be halted or altered. Under less severe conditions, visibility impairment may not even be noted by the individual, but in fact is reduced to such a degree that automobile accidents are more likely to occur.

Conversely, some behavior by individuals contributes to the community air pollution problem as well as to their own specific likelihood of being affected. Some occupations expose people to severe polluted conditions for long periods of time and then have an unusually high risk factor of morbidity and mortality. Occupations such as traffic policeman, automobile mechanic, and truck driver immediately come to mind. In addition, cigaret smoking, use of fireplaces, use of certain methods of cooking, and of aerosal sprays all contribute to individualized air pollution.

Our future studies will explore these facets of human behavior, as well as others, in an attempt to measure the effect of air pollution upon human behavior in the Lake Arrowhead region.

C. Organization of the Human Population. The environment, technology, and human population structure (spatial distribution, etc.,) and organization are related to air pollution. Through its use of the environment and its impact upon the environment through its technology, the human population is responsible for most air pollution and is the only species that can do anything about overcoming the air pollution problem.

People residing in large population concentrations are ordinarily organized around urban life forms and use the environment in certain ways which produce air pollution. In Southern California this air pollution drifts to the Lake Arrowhead region, and elsewhere, and is added to locally produced oxidants. From a broad context, then, the entire metropolitan complex, as well as local, state, and federal influences, is important in studying the local air pollution problem. A study of the political impact and influence which various individuals, groups, organizations, and industries have upon decision-making at the local, state, and federal level in regard to air pollution (its control, management, and effects) is imperative in the study of the organization of the human population and its impact upon the environment.

On a more localized scale, a study of the ways in which the problems of air pollution in recreational areas can erect barriers or precipitate effective local and extra-local public action is important. The communication and determinants of public information and consequent attitudes toward various alternative solutions are substantially a product of the social organization of the population. The human population's response to air pollution in the local communities should have an impact upon local communities and their organizational structure. That is, there could be attempts by local permanent residents, as well as intermittent residents and visitors, to influence local, state, and federal officials in the use of social power, management techniques, etc., in order to overcome air pollution. In this regard, assuming that air pollution will shortly become a very salient issue to the residents of the Lake Arrowhead region, organizations will soon be established to combat air pollution. Some of these organizations may be associated with extra-local organizations formed to combat air pollution and other environmental hazards on a larger scale.

Will these organizations have an influence upon regulatory measures designed to control technology? Will there be effective attempts by individuals and organizations to influence management systems in regard to air pollution? How will the management systems be brought into being? Who will manage the management systems? How effectively will they implement controls? All of these aspects need to be examined at the local level and tied to state and federal social power systems.

D. Organizations. How people behave and how they organize in activities related to air pollution is the essence of our concern. People may organize, either in formal or informal groups, to study the problem of air pollution and the effective means of initiating local and extra-local public action; to discuss various alternate solutions; to evaluate the monetary, health, and other costs of air pollution; to influence local, state, and federal officials in the use of social power in an attempt to overcome air pollution; and to study the impact of regulatory measures in controlling technology and energy use.

Currently, there are no local organizations in the Lake Arrowhead area concerned with air pollution in the region. There have been attempts by a few isolated individuals to combat pollution, but there have been no organized efforts in the region to influence local, state, and federal officials to overcome air pollution. Given the heavy damage from air pollution that is expected to become highly visible over the next few years (e.g., thousands of trees dying), it may be expected that some local organizations will be formed to combat air pollution. In addition, it is expected that there will be concern expressed over the increasing recreational use of the area and the possiblity of undesirable housing, apartments and condominiums being built, and how various solutions may be effectively implemented through enforcement of regulatory measures.

The form that organizations may take are varied, and the impetus for organizations may be local or extra-local. With the aid of "experts" in air pollution, organizations may be formed which essentially will utilize local "voluntary" participation. Discussion groups and educational meetings should be helpful in allerting local persons to the air pollution problem and the means by which they can do something about it. Another "community organization" approach is to focus on conflict rather than on discussion and education. Here organizations which stress the external nature of the "enemies" from other regions (e.g. the L. A. Basin) and how local residents may combat them would be the focus. Hostility toward outsiders, including government and industry, is apparent in this approach to meeting the problem. In both instances, organizations might be formed which would act as "watch dogs" over public agencies who are charged with air pollution control and management responsibilities.

Others, of course, argue that there is more to overcoming the air pollution problem than organizing or acting as watch dogs. Molitch (forthcoming) argues that the problem of air pollution is not simply one of obtaining the right kinds of information and acting upon it, and points out that there are vested interests in the continuation of air pollution. This perspective asserts that the use, control, and knowledge of social power is the only way that technology, which is producing air pollution, can be effectively managed and brought under control. An organized and mobilized public wielding its power would be a factor to be reckoned with and would make air pollution more than a symbolic issue. That is, laws would be enforced and have a real impact upon controlling air pollution.

E. Economic. It must be made explicit in any discussion of the costs of air pollution that social values are inherent in the concept of "costs". In estimating costs, reliable and valid measurements are necessary and these costs will vary according to the point of view of those who are calculating them.

Further, trade-offs and alternative control management programs only make sense when one considers the point of view of those who are making the estimates, and from what value vantage point they are making the estimates. The "emmitors" and "receptors" do in fact have different views of the necessity of risks and how much should be spent to avoid certain levels of risk. Monetary costs in converting old plant equipment and transportation vehicles to acceptable levels (by whose standards?) and the building of new plants and vehicles can probably be estimated fairly accurately. However, social and health costs are virtually impossible to measure with any precision. For example, in regard to the effects of air pollution upon health and mortality, how does one measure the cost of a father or a mother to their children? How much effect does air pollution have on present and future earnings, on average duration and severity of temporarily disabling and efficiency-reducing capabilities, on permanent disabilities, on increased probability of morbidity and mortality from other diseases, and on absentism at work and at school? Further, how can one estimate air pollutant costs in its impact on the size, composition, distribution and income of the population? Finally, what would it cost to find and treat victims and what costs accrue to those who attempt to avoid air pollution all together (Weisbord, 1961; Butler, et al, 1972)?

At a somewhat different level, an investigation is needed to evaluate air pollution effects in high and low pollution areas by measuring the need and cost of more frequent painting of the exteriors of housing, the time spent in routine housecleaning, the hours of use of garments between cleanings, the expenditures on laundering supplies, the frequency of washing cars, and the willingness of the public to pay for the amelioration of air pollution, and finally, the effect of air pollution upon property and rental values. These factors suggest that air pollution has costs other than those ordinarily anticipated (Ridker, 1967).

For this project, our concern would be mainly with the costs that the public pays in regard to morbidity, mental well-being, perceived costs of air pollution, and what the public would be "willing to give up" in order to solve the impure air problem. These facets are discussed at more length below. The questions are related to "who will pay and how much is it going to cost them?"

F. Health and Mortality. Goldsmith (1968) has pointed out that "a man can live for five weeks without food, for five days without water, but only five minutes without air". He further suggests that before the effects of air pollution upon health can be determined, the following requirements must be met: (1) pollution, or an index of it, must be measured; (2) one or more effects must be measured; (3) a relationship between the two must be shown--pollution and its effects.

The few studies accomplished to date suggest that premature infants and the infirm are highly susceptible to air pollution. Most suceptible, however, are the aged. Goldsmith further lists the effects of air pollution and argues that they are differentially distributed among the different ages and medical statuses: (1) acute sickness or death; (2) chronic diseases, shortening of life, or impairment of growth; (3) alteration of important physiological functions such as ventilation of the lung, transport of oxygen by hemoglobin, dark adaptation (ability to adjust eye mechanisms for vision in partial darkness), or other functions of the nervous system;

(4) other symptoms, such as sensory irritation, which in the absence of obvious cause might lead a person to seek medical attention and relief; (5) discomfort, odor, impairment of visibility, or other effects of air pollution in sufficient strength to lead individuals to change residence or place of employment.

In studying the above human responses to air pollution, Goldsmith (1968) presents a cogent argument for the most sensitive measuring instruments possible since almost any level of effect upon some individuals will seriously effect others. There is an additional problem of ferreting out the characteristics of persons with different thresholds of resistence to air pollution.

Goldsmith concludes from his review of the literature that individual pollution, cigaret smoking and the like, is a major causal factor in lung cancer whereas community-wide air pollution is, to date, only a "suspected" factor. Sufficient exposure to air pollution appears to be a factor in chronic bronchitis and emphysema, although probably it is not the only causal agent. There is some evidence that cigaret smokers are more susceptible than non-smokers in a common polluted environment. Furthermore, there is evidence suggesting a link between air pollution and asthmatics. The available studies are not definitive because few of them have sorted out individual air pollution from community air pollution. One obvious solution is to study young children. When this has been done, the studies indicate "a strong case for adverse effects of air pollution on lower respiratory tract conditions" (Goldsmith, 1968).

Little data exists which establishes a relation between air pollution and mental well-being. However, a series of studies conducted in California during 1956-61 indicate that perception of air pollution is associated with feelings of overall malaise as well as physical symptoms such as eye irritation, asthma, nose complaints, headaches, and chest pains. Further, these complaints were more prevalent during periods of high air pollution counts than during favorable weather conditions.

No studies to our knowledge have examined the effects of air pollution on the health of the population in the Lake Arrowhead region. The methodology to measure most health effects exists and the health of the human population in the region will be one of particular importance for future investigation in the Lake Arrowhead habitat.

Research has demonstrated that periods of unusually high air pollution are associated with small increases in excess mortality--that is, mortality beyond that ordinarily expected on a normal probability basis. Several problems exist in measuring air pollution's effect upon mortality in the Lake Arrowhead Region. First, ordinarily a very large population is necessary so that excess deaths can be estimated, unless there is a "disaster" such as the ones in Donora, Pennsylvania in 1948, London in 1948 and 1952, New Orleans in 1955, and world-wide in 1962 (Goldsmith, 1968). Second, the intermittent nature of a substantial proportion of the Lake Arrowhead population precludes precise estimates of the effect of air pollution in the region upon the mortality rate. The mortality that does occur will vary substantially by subregion because the population age structure is highly variable. Research suggests that the most susceptible to air pollution mortality are the aged, infants, and those with antecedant history of respiratory and/or heart problems.

V. FUTURE STUDIES FRAME OF REFERENCE

In a broad-based ecosystem approach to the study of the human consequences of air pollution in the Lake Arrowhead region, the following could be used as a starting point for the long term research endeavors to be undertaken by the social science inter-disciplinary team. Four primary elements make up the approach: (1) Environmental Studies, (2) Technological Inputs, (3) Human Population Structure, and (4) Organization of the Human Population (Duncan, 1961). Each of these segments are discussed individually and then they are briefly incorporated into an overall research scheme.

(1) Environmental Studies. In our terms, environmental studies are all those endeavors that involve research concerned with vegetation cover, animals (other than Homo sapiens), soils and hydrology, and air monitoring and meteorology. We have assumed from previous discussions and proposals from the committees in each area, or in each particular sub area of investigation, that particular "models" will be developed, as well as models linking together these various sub models.

These environmental research endeavors, along with technological background data, are extremely important to the social scientists in furnishing the necessary independent variables needed to measure the impact of air pollution upon the human population and ecosystem. Environmental studies will make available to the social scientists objective measurements of the products of technology (air pollution) and objective measures of environmental changes brought about by technological inputs. Air pollution probably has a direct effect upon individuals, but we expect that relevant effects for social policy come only when large numbers of individuals begin to perceive that the environment is drastically changing, e.g., the trees are dying, and ascribe the cause as air pollution. In short, environmental studies would give us objective measures of the changing environment. The social scientists' contribution would be to measure the impact of these objectively measured inputs of air pollution and environmental changes upon human beings.

(2) Technological Inputs. The study would use technological data only in a descriptive sense. Social scientists are interested in the sources of pollutants, whether industry, automobiles, or any other sources. However, social scientists will be interested primarily in technology as it produces air pollutants and whether any environmental changes as measured by the natural and physical scientists in the region can be attributed to these by-products of technology. Further, we will be using as key aspects of our study environmental changes in the Lake Arrowhead region made possible by changing technology, resulting in construction of freeways, bridges and transportation networks that make accessibility to the region simpler for larger proportions of the human population residing in the greater Los Angeles metropolitan basin and elsewhere.

(3) Human Population Structure. Social scientists, of course, are concerned with human populations. We expect to be concerned with the demography of the region: migration patterns, fertility, morbidity, and mortality. We would be especially interested in describing the population in absolute numbers and density, by various sites in the Lake Arrowhead region. Both

number and density are highly variable in this region because of the extensive recreational land utilization. The permanent, intermittent, and transient populations need to be considered in any research design in the Lake Arrowhead region. There are changes in absolute numbers and density of population as results of the in-and-out-flow of people at various times and seasons. In addition, measures of morbidity, mental and physical health, and their interaction with socio-economic status are important. Data from various hospitals, the Kaiser Medical Plan, and individual medical practitioners would be invaluable. In all the above population characteristics, measurement of perceptions, knowledge, attitudes, and behavior occurring across time as the environment begins to change and possibly deteriorate are especially important.

It is possible, of course, to determine if changing knowledge and attitudes about air pollution are translated into meaningful attempts to change the technology's impact upon the environment. Individual behavior such as selling property and moving away from the region or no longer visiting it on an intermittent basis are examples of possible behavioral manifestations. Psychological mental stress that air pollution may or may not have upon the individual and the impact of pollution upon various value systems that the population may hold in regard to government, politics, and social problems, would be another focus of research. What are the political implications if the recreational use of Lake Arrowhead declines? Social scientists would be concerned primarily with the extent of knowledge about air pollution, attitudes toward air pollution, and how air pollution effects behavior of the population living in the area. In addition, they would be concerned with the kind of support the population would give to abatement or management systems. A human population based model would incorporate many of the aspects that are included in other models discussed in this report. A basic assumption is that perception and behavioral manifestations of air pollution varies by morphological and social characteristics including age, sex, social class and so forth. Not only does perception vary, interpretation of what can be done about the particular problem varies by morphological and social characteristics. These notions lead us to the fourth element in our ecosystem frame of reference.

(4) Organization of the Human Population. When social scientists discuss the organization of the human population, they are in essence describing behavior of the human population, in social groupings; that is, where and how they interact in social groups for some particular purpose. The communication and determinants of public information and attitudes regarding the existence of the problem and determinants of attitudes toward various alternative solutions would be examined. Problems of use-management, land development, commercialization, and historical patterns of economic exploitation of area resources, and comparative problems of polluted (e.g. Lake Arrowhead) vs. relatively non-polluted (e.g. Big Bear or Idyllwild) areas would be of interest to social scientists. What impact has all of this upon the perception of Lake Arrowhead as a place "to get away from it all", its perceived "natural beauty", and its healthful living?

The population's response to air pollution in the local area in an organizational sense such as the attempts by local permanent residents, as well as intermittent residents, to influence local, state, and federal officials in the use of social power in an attempt to overcome the air pollution problem is directly relevant here. In this regard, then, the study of the formation of local and extra-local groups and the process they use to combat air pollution and other environmental hazards would be mandatory.

Within the same frame of reference, the impact which local, permanent, and intermittent residents have upon regulatory measures attempting to control technology needs to be studied. These regulatory measures include varying energy usage as well as the type of energy usage, family size limitation, disposal techniques, and economic controls upon various kinds of technological inputs to the environment that create pollutants, i.e. automobiles and factories. Are there any effective attempts by individuals, either permanent, transient, or intermittent, to influence management systems in regard to air pollution? This would include how these management systems were brought into being and how they are implemented. All aspects of local, state and federal social power systems could be examined. Again, the model, or models, derived from our analyses would be integrated with the other models developed focusing on technology and environment to form a larger ecosystem model.

Briefly, the total system views the relationship between the environment and technology at the beginning of the causal network. Technology's impact upon the environment has implications for the structure of the human population, including absolute numbers, density, age structure, migration, fertility, mortality and morbidity; and for how the population is organized and in what fashion it is organized in relation to changes in technology and the environment.

If social scientists and their orientations or approaches are to be considered in this particular research endeavor, they need to have some input on "site" selection, which should include a representative sample of uninhabited and habited sites. Habited sites would include those sites which are exposed to transient use, and would include wilderness areas in which virtually no people are found as well as picnic grounds and camp sites which have substantial and continual use by transients; Intermittent-permanent areas, which includes sites of weekend and/or summer visits by owner-residents and/or renters; and Permanent residential areas or sites which includes various subareas in which the majority of people reside the year around. The use of aerial photographs of the region would be useful here in assessing differential tree damage to selected sample sites with varying human population usage. The severity of the problem may be related to the input of sheer numbers of people which may itself result in differential impact upon the forest, as well as air pollution. Environmental data on these specific sites allows a linking of actual environmental changes to the structure and organization of the human population.

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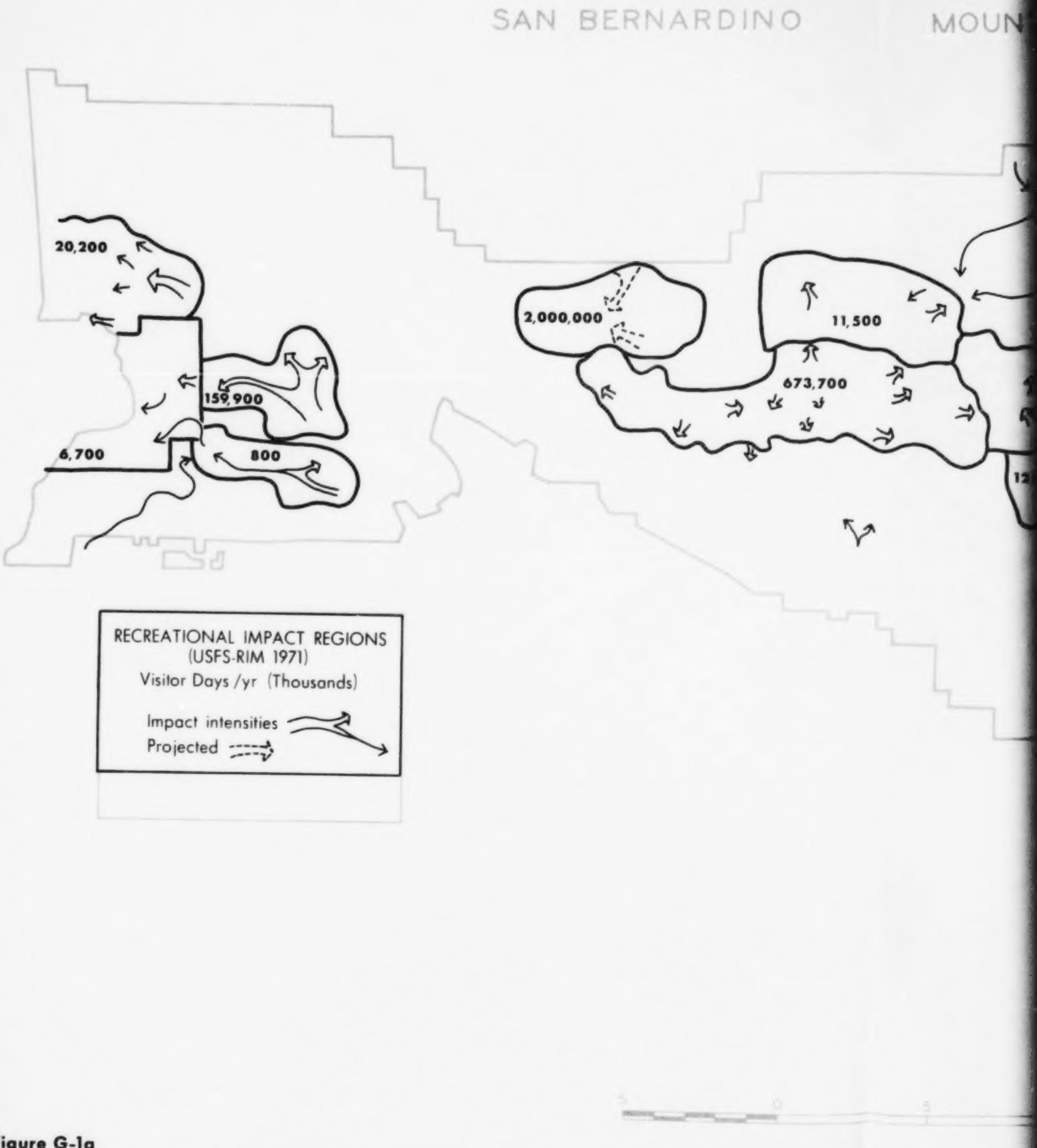
SAN BERNARDINO
MOUN
20,200
2,000,000
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673,700
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RECREATIONAL IMPACT REGIONS
(USFS-RIM 1971)
Visitor Days /yr (Thousands)
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5
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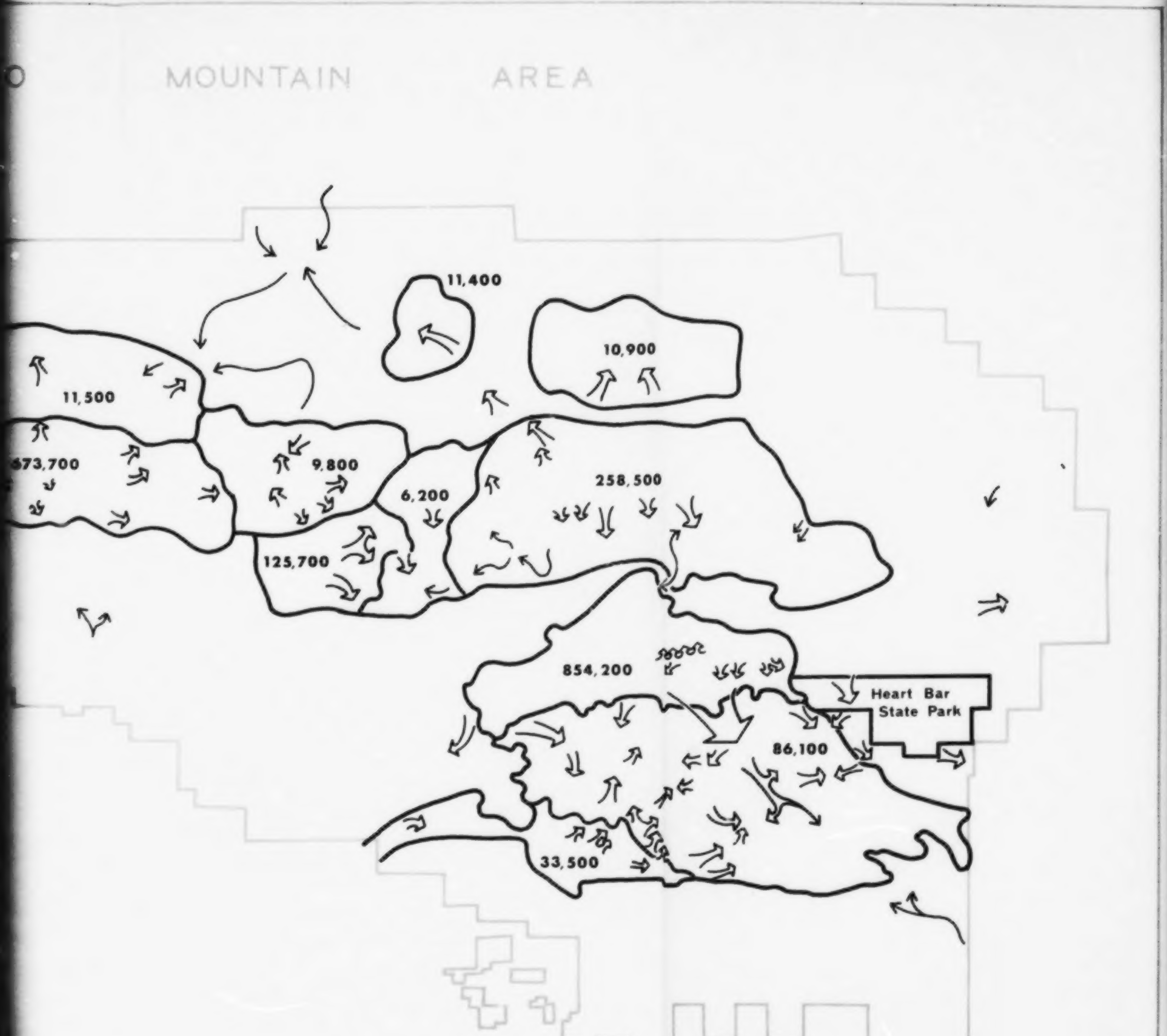

O MOUNTAIN AREA
11,400
10,900
11,500
673,700
9,800
6,200
258,500
125,700
854,200
Heart Bar State Park
86,100
33,500
5
10 MILES

The Impact of Oxidant Air Pollution on the Mixed-Conifer Forest Ecosystem--Systems Integration

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The Impact of Oxidant Air Pollution on the Mixed-Conifer Forest Ecosystem--Systems Integration

Three inter-related components to the Systems aspect of this study are:

1. Modelling
2. Information System
3. Systems Coordination and Integration

Each component has specific attributes that can be described independently of the other components.

The components themselves, however, are not independent. Design of any component will directly affect in significant ways the other components. It is therefore wise to take a unified approach to development of all three components. The Systems aspect of the study is built by linking the components together into a functional unit.

The need for a Systems approach to an ecological study such as the one proposed for the San Bernardino Mountains can be summarized with the following observations.

1. Extensive resources must be brought to bear on the problem, including large-scale funding, and numerous technical and research personnel.
2. A large, very diverse data base will be generated to study the problem.
3. The problem is complex (because the system is dynamic and interactive), multidisciplinary in content, and subject to redefinition during the course of investigation.

4. Both the data and the personnel must be coordinated for systematic progress toward solution of the problem.

These observations suggest the first-order constraints and priorities on the design of the Systems aspect of the study.

Modelling

Preceding sections of this report clearly bring out the great complexity of the mixed conifer forest, even though relatively little is known about this ecosystem. Also, the high degree of interdependency cutting across traditional disciplines is brought out well in the sections on plants and arthropods, and in the summary.

As a result of the studies on population dynamics of western pine beetle and large-scale synthetic pheromone field evaluation tests that have been done at the University of California, Berkeley, and the Pacific Southwest Forest and Range Experiment Station, U.S. Forest Service, Berkeley over the last few years, there is detailed information on a small portion of this mixed conifer forest system. This system includes adult ponderosa pine, root diseases, and western pine beetle with its parasites, predators, and other associated insects, all of which form an intricate network of strong interactions that are generally non-linear, showing thresholds, saturations, and state-dependent time delays. Important interactions are discrete and stochastic and many of the processes are sequential in the sense that past history strongly affects present and future behavior.

There does not seem to be anything unique about the small portion of the forest that has been studied in detail; thus there is every reason to believe that the remainder of the forest will be at least as complex and functionally similar in its interactions.

Flora and fauna of this region have co-evolved over an extended period of time and in spite of interference by man the system is still reasonably intact. It appears that interactions between the major conifer species and between the conifers and other plants, insect pests, disease, soils, climate, and fire, are such that dense, even-age pure conifer stands are unstable. The forest breaks up into a mosaic of different species which shift their position through time. It is only man's short life span that makes it difficult to appreciate how dynamic the mixed conifer forest is. It is a system that may change significantly and rapidly under the impact of oxidant air pollution damage.

It is not clear how one could - or even if one should - try to manage the stand to compensate for damage caused by air pollution. Such a highly complex, non-linear system may be quite counter-intuitive in its response to direct manipulation. The forest is responding to a constantly changing physical environment: daily and annual cycles, shifting weather patterns, short- and long-term changes in climate. The system may have multiple equilibrium points or under varying input no equilibrium at all. It could turn out that extensive, selective air pollution damage to the forest could so alter the composition of the forest that it would never return to its original state even after air pollution levels were reduced.

Different mortality patterns could produce differing attitudes toward the smog damage. If in an area of fairly uniform conditions the ponderosa pines declined at approximately the same rate, the trees could decline for a period of ten or fifteen years without much increase in mortality, and then having reached their physiological limit at roughly the same time a large portion of the trees could die over a few-year period. White fir and incense cedar in the understory of the ponderosa pine forest would be released and would eventually grow to produce many years later a new forest of white fir and incense cedar. Another possibility is that the microclimate and soil conditions would be sufficiently varied and the genetic resistance of individual trees would differ enough so that the ponderosa pine mortality would be widely distributed over time and space. As individual trees died this would release fir and cedar in their immediate vicinity and the stand gradually would be converted from a ponderosa pine forest to a white fir and incense cedar forest. A third possibility is that by the time the ponderosa pine was dying from air pollution there would be sufficient damage to the fir and cedar so they would be stunted in their growth, and consequently as the ponderosa pines died the forest would be invaded by brush species. Even though the same number of ponderosa pine eventually died, people would probably react very differently to each of these three cases.

It would be very desirable to predict the course of change in the forest under different patterns and levels of air pollution. What would happen if the levels of air pollution remained essentially the same into the distant future or if air pollution was to gradually increase? Would the forest be eliminated entirely? Far stricter air pollution standards and control methods are proposed for 1975-76. If these controls were to significantly drop the levels of oxidant air pollution in the Los Angeles basin, what effect would this have on the mixed conifer forest? Would the changes in the forest be significantly different if the reduction was delayed until 1980 or 1985?

Also it would be desirable to know if there were any practical ways of manipulating the forest to at least partially compensate for the damage caused by oxidant air pollution. Any management of the forest to compensate for air pollution damage would have to involve economic considerations over an extended period of time. An annual expenditure of a few percent of the total value of the forest is all that would be practical. This means that any manipulation of the forest would have to be limited and selective. To be effective it would have to be well integrated with the naturally occurring processes in the forest.

Trying to predict long-term changes in the forest resulting from air pollution damage through direct experimentation will have only limited value. Forests are simply too extensive in space and time to be a reasonable object for experimentation. Spatially, forests are functionally intact ecosystems of tens to hundreds of square miles. Temporarily, the major tree species of the mixed conifer forest have potential life spans of 300 to 400 years and generation times of 50 to 100 years. A single tree is not a forest. Even a square mile of forest in isolation would show abnormal patterns of reproduction, dispersion, growth and death, interacting with fire, disease, and insect pests in an atypical manner, thus changing the dynamics of the system and the successional patterns.

Experimental science is most effective as a multistage process where the design of each experiment is based upon the information and knowledge gained from preceding experiments. Unfortunately, it is difficult to see how one could even carry out a single controlled experiment that would be extensive enough in space and time to contribute significantly to understanding successional processes within the mixed conifer forest. About the only possible approach to understanding the forest would be to experiment with many of the components of the forest under a variety of conditions over a short period of time. The forest is a diverse mosaic of animals, plants and physical conditions. A wide range of naturally occurring experiments on various components of the forest is continually in progress and needs only to be monitored. In addition, these experiments can be supplemented with artificial field and laboratory studies to elucidate specific features of the forest system. However, data gathered in this manner are not in a form suitable for predicting the long range consequences of oxidant air pollution on the mixed conifer forest. Nor are the data suitable for exploring various management strategies which might be used to at least partially compensate for the damaging effects of air pollution on the forest.

Experimental data must be transformed from an organization describing changes in the system for many varied conditions over a short period of time into one showing changes for a particular set of conditions over an extended period of time. These reorganized data could then be used to predict the long range changes in the composition of the forest under different concentrations and distributions of air pollution through time. Also, one could explore, under different patterns of air pollution, the consequences of strategies aimed at reducing damage or mortality caused by disease, bark beetles, mistletoe, and animals that consume cones and seed. It may be that over an extended period of time, at the present levels of air pollution, it will be impossible to maintain ponderosa pine, but that under proper management conditions a forest of white fir, incense cedar and sugar pine would be stable.

Perhaps it would be well to stress again the impossibility of answering these questions through direct experiment. It simply is not feasible to directly explore through experimentation the effects of different management strategies or patterns of air pollution over tens to hundreds of square miles of forest and decades to centuries of time. Complex, non-linear, multiloop systems with state-dependent time lags are counter-intuitive in their properties. To successfully control such a system one has to anticipate future states and compensate for conditions in the future rather than those of the present. Since, in general, different processes have different delays associated with them, a whole array of future states of the system must be anticipated to successfully control the system. Trying to manage a system of this complexity by responding to present and past states of the system almost certainly will be ineffective and can even produce changes contrary to those desired. Thus the successful prediction or management of a system with such a structure depends on having validated, quantitative, predictive mathematical or algorithmic models. The construction of these models from many small, short term, indirect experiments must be a central activity in any effective study of the dynamics of the mixed conifer forest.

The formation and transport of oxidant air pollution is an exogenous variable in this study. There are other extensive studies investigating these problems from the analytical and algorithmic modelling approach.

Direct effects of oxidant air pollution on the hydrology of the system is probably negligible. The emphasis in hydrology would be to monitor water quality and other hydrological aspects to determine whether indirect effects of air pollution on vegetation would affect the hydrological system. Until such effects can be demonstrated, modelling of the hydrology of the system must be considered external to this study.

Modelling efforts on systems of the nature and magnitude of the San Bernardino forest ecosystem, such as the IBP Biome studies, have been investigating the concepts of productivity, energy transfer and nutrient cycling. Because of this emphasis their approaches to modelling have been radically different than those required for this type of study.

The San Bernardino National Forest is no longer based on a timber producing economy. Its main value is as a recreational and watershed site. For recreational value, the forest's significant attributes are described by its structure; species distribution, abundance and diversity, age distribution of its principal floristic components, wildlife diversity, and the abundance and quality of its surface water, among others. These attributes combine to produce the aesthetic qualities required in a recreational forest setting. They also describe the parameters which must be manipulated by forest managers. Predictive models of this system would therefore have to include these attributes into their own structure, for there is no clear relationship demonstrated between such concepts as productivity and floristic diversity that would be useful to this problem.

Very little work has been done that considers the forest structure within the framework of a dynamic model. There is an abundance of literature that describes static models of such things as species diversity and distribution. These models give little insight into the underlying mechanisms that drive the system and are of no use in simulating the dynamics of a system subjected to different management strategies, or to such stresses as air pollution.

Analytical models applicable to a system of the structure described here can be found in the area of mathematics dealing with stochastic processes. General summaries of the mathematical theory can be found in Karlin, 1966, and Harris, 1963. Examples of the application of stochastic theory to biological problems in population ecology are found in Chiang, 1968, and Reddingius, 1971.

Several computer languages which have recently become available will facilitate the design and implementation of synchronous and asynchronous stochastic algorithmic models. These include APL/PLUS as implemented on UCLA CCN's IBM 360/91 computer, and SIMSCRIPT II.5 as marketed by Consolidated Analysis Centers, Inc., Los Angeles, Calif.

Information System

Modelling and other analyses performed during this study will, of course, be driven by real and simulated data. These data will be accumulated from various sources throughout the study, principally from the field, and secondarily from literature and simulation studies. Because of the magnitude and complexity of the study, careful attention must be given to the problem of data base generation and management. Early planning and development of an Information System will result in a more fully coordinated study, and will produce long-run economies in people-time and in data processing.

General observations about data management in this study are:

a. Data are not usually gathered in the order in which they are to be accessed for analysis.

b. Data describing many parameters of the system must be simultaneously accessed during analysis.

c. People are not very adept at performing manually the tasks implied by a. or b.

d. Data are structurally very diverse.

e. Data are qualitatively very diverse.

f. There exists substantial a posteriori information about the diverse structural and qualitative attributes of data, and about the multiple ways in which they will be used.

g. This information can be used to enhance--or even to make possible--the ability of researchers to "get at" the data.

h. Electronic data processing (EDP) provides the necessary medium to perform these tasks well.

i. However, it is necessary to effectively interface the technology of EDP with the user, in this case the ecologists in the field and other investigators.

In order to accommodate these observations the following structure is recommended. The Information System should be divided into three well-integrated subsystems. First, for input, there should be a data capture (data recording, verification, and editing) subsystem. Second, for manipulating the data, there should be a generalized file management subsystem. Third, for output, there should be a data interpretation (reduction, analysis, report generation, and graphics) subsystem. Each of these subsystems would operate on different data bases, each usually being generated from output of the preceding subsystem.

1. The data capture subsystem presents the most difficult problems regarding human engineering requirements which are very necessary to consider in this subsystem.

It is at the point of data capture that the greatest opportunities to generate unrecoverable errors usually occur in ecological studies. There are numerous reasons that can be suggested to support this contention. Much sampling in ecological studies is manual in nature. Automated recording stations and devices, although commonly used for certain applications, are generally not available; e.g. they do not exist, they cost too much, the technology is not developed, etc. It is necessary therefore to design the data capture system to reduce errors generated by common human problems such as fatigue, fallible memories, boredom with repetitious tasks, illegible and ambiguous handwriting, and individual competency.

Each, or even several, of these traits may be of minor concern in a study where the principal investigator is the only participant. He can generally decipher his own handwriting. Also, he is probably more aware of the consequences of deviation from the defined tasks since he has a "world view" of his project.

In a multi-disciplinary project with several to many principal investigators and technical support personnel this is not true. In this situation each person's contribution represents only a small part of the overall project. This does not imply that it is an insignificant part, nor does it imply that each part is unlinked in a multiplicity of ways to other parts of the project. The data that are entered into the system, then, must be "available" to others, i.e. they must be rendered into useful information. Raw data must therefore be legible, commensurate with other similarly gathered data, of identifiable origin, and accurately entered into the system.

In addition to the human problems of data transfer, there are other reasons to make every effort to develop good management techniques for data capture. It is frequently not possible to "re-capture" data that have been lost, destroyed or otherwise rendered not usable. One such situation occurs with destructive sampling where the measurements cannot be taken twice.

Another situation that frequently occurs in ecological fieldwork is the observation of what may be termed "rare" or "unusual" events, or "opportunistic" observation. Measurements acquired on such events frequently provide useful insight into the problems being studied. Suitable ways to incorporate these observations into the data base should be developed. Otherwise, they get recorded as miscellaneous notations in the margins of data recording forms and are left behind during transcription.

Measurements taken on time-dependent parameters cannot usually be repeated since they are only meaningful in their proper time-frame relationships to measurements on other parameters.

Even after every reasonable effort is made to prevent accidental loss of raw data, errors are still going to be introduced into the data base. So, data verification (against the original copy) and editing (of the errors uncovered) must be included into the data capture subsystem. The process of "checking" the digitized data against the original data should be done by those responsible for having generated the original data. They are usually the ones most likely to recognize any of a multitude of discrepancies that can and usually do occur. This procedure can be optimized to simplify the process and to reduce the time required to do the checking.

II. The generalized file management subsystem is the least problematic to acquire or design since two suitable options are already available. They differ from each other substantially in structure and investment in resources.

Within government agencies there are (or will be) several file management systems of particular usefulness to ecological studies of the type proposed. The USDA Forest Service is currently negotiating the establishment of GIM (General Information Management system). It may be available by summer, 1973. It is proposed to be available on a nationwide network of Computer Sciences Corporation of Los Angeles. It will probably be relatively costly to use but this is far from determined yet.

Another system reputed to be quite useful is RECON, the NASA Information System. Its availability is undetermined.

Although systems such as these may be available, the practicality of using them would involve major considerations of convenience, as well as of costs and other more technical factors. File management is only one of the three subsystems needed in the Information System. These file management systems are not available at all computing facilities. Conversely, other necessary computational tools (to be used in the data capture and data interpretation subsystems) may not be available at the installations having file management systems. Given limited resources, the solution normally involves some substantial compromise such as abandoning the best of one world and making do with less. Two such compromises might be to:

A. Physically transport data (on some machine-readable medium such as magnetic tape) from one installation to the other. This permits the continued utilization of desired software resources. However, the time delays can be devastating to productive use of researchers' time. Ideas will continually be tested against the data base. Efficient interactive capability between the investigator and the data permits the continuity of thought processes that must be part of any research program. This is even more critical when several investigators must participate in a multidisciplinary environment. The quality of the communications system can be the determining factor in the success of a project.

B. Determine whether the "robustness" of a computer center's resources is sufficient to allow a useful information system to be developed without the services of a sophisticated file management subsystem. A measure of such robustness would include considerations of languages diversity, utility routines scope, communications features, size and cost of processors and peripheral storage, and other factors. Given a system robust in other resources, it is possible that more programmer time can be dedicated to "managing" files to compensate for the lack of a more automatic system.

Obviously, the turn-around time under the latter compromise should be shorter (and balanced in other ways, such as in cost) to be competitive with compromise A.

An effective interactive information system is needed not only for the investigators but also for the programmers who support the principal research personnel. Although the principal investigators are able to distribute their workloads among multiple obligations, such as teaching, committee meetings, field work, and data interpretation, the programming staff is generally dedicated solely to design, implementation and execution of programming support. Effective utilization of programmers' time is best served by a highly interactive computing environment.

Ecologists have made little use of sophisticated file management systems in the past. (Indeed, such systems have not been available except during the past few years, and they are not widely distributed.) There is still much to be learned about how best to interface them into ecological studies. A definite need for them is indicated, however.

III. The data interpretation subsystem receives raw data from the various files created previously and processes them to eventually produce information that can be interpreted by the researchers. From this process future emphasis and direction of the study can be planned. This planning and re-planning permits refinements to be incorporated into the study plan as more is learned about the system. For, although there is general agreement that the forest-smog system is degenerating and should be studied, no one would suggest that we know exactly how the study should proceed.

The tools and techniques used in data analysis will strongly reflect the experiences and biases of the individual investigators, which are varied and many. Because systems such as the San Bernardino National Forest are poorly understood, it is certain that a variety of techniques will be applied to analyze the behavior of this system. Many of these techniques are themselves under development, and new ones will undoubtedly be formulated.

It is therefore reasonable to provide a great degree of flexibility to design new methods of analysis. This flexibility would be based upon having a broad spectrum of computing languages and associated resources available. They would include as a minimum, APL/PLUS, PL/1, FORTRAN and SIMSCRIPT II.5. An array of languages such as these will allow ideas to be rapidly implemented in the most natural manner to test the validity of the method. If proven to be useful, then full-scale implementation for overall efficiency can be pursued.

Systems Coordination

The necessity to provide a formally recognized mechanism for coordination and integration of a large multidisciplinary study is obvious. No one person will be able to assume sole technical direction for the project. The scope of the project is too broad for one person's technical competency. Too little is understood about the system to know well how to study it. There has been only enough experience in multidisciplinary studies of large ecological systems to indicate that having less than a broad-based technical decision-making committee will assure that serious deficiencies develop and persist in planning and executing the study.

First, then, it is recommended that a technical decision-making (DM) committee be an integral part of the study. This committee should have representatives from each of the major disciplines involved in the study. The committee would be responsible for on-going evaluation of progress, and for providing solutions to the many major logistic and technical problems that will arise during the study. It would also have the responsibility to propose the direction and priorities for future research. Since it is to function as a multidisciplinary committee, its members should be selected for their proven ability to function in this type of disputatious atmosphere. This technical DM committee will function well only if it has effective communication lines established within itself, and with the remainder of the project. Three essential lines can be considered the minimum configuration.

First, there should be a full-time Field coordinator. This person would have the responsibility to assure that plans are implemented and carried on as required, or to determine why they cannot be carried out. The Field coordinator must be a broadly-trained individual, one who can communicate effectively, and who is resourceful. This person is possibly the single most critical participant in the study, since he assumes the responsibility to determine that a well-planned study is actually being executed.

A second line of communications should be established between the committee and the Information System. This may be done through an Information System coordinator, a person with the responsibility to coordinate development and implementation of the various Information System subsystems. He would establish priorities for data processing based on information supplied by the technical DM committee. He would work with the Field coordinator to determine the characteristics of data capture processes of the various investigators. This will provide further necessary information to design and operate a more intelligent Information System. He would keep the technical DM committee informed about the status of the Information System, i.e. progress, problems, requirements, etc., associated with proper functioning of the System. He would work with the Modelling coordinator (discussed below) to establish System requirements of that effort.

A third line of communications, the Modelling coordinator, would have primary responsibility to bring together the group of investigators for the purpose of constructing a model(s) (representation) of the system under study. Since the model will necessarily be a limited view of the real system it is most important that the particular view represent the best information available. Therefore, all principal investigators should be expected to participate in the formal modelling effort. As indicated previously, the model will be driven with real and simulated data. Much of the real data are to be generated during the study. (As indicated in other parts of this report, there is a paucity of information on many important components in the system.) Data collection and modelling efforts must then be run concurrently to assure that the information needed for the model is indeed the information being gathered in the field. The Modelling coordinator would have the responsibility to determine that goals of the study are correctly represented in the modelling effort. He would develop a framework for the overall modelling strategy and be responsible for its updating or modifications as necessary.

The two most important points to be derived from the above discussion about lines of communication are that 1) there do exist several critical points of coordination, and 2) participation in group interactions is essential. From this it should be concluded that special effort must be made to place reliable people in those positions of coordination, and that all principal investigators should be expected to convene frequently to contribute their talents to the modelling project. Needless to say, a substantial travel budget should be established within the Systems component of the study to be able to bring people together.

One other manpower component must be discussed within the framework of Systems coordination. This project will need a number of full-time investigators to support the principal, or as VanDyne, 1972, refers to them, contractual investigators. On countless projects the graduate student has traditionally filled this role. He had, by this stage in his career, developed sufficient tools to be productive. He is generally highly motivated and has a vested interest in contributing to the success of a project.

A graduate student does have serious restrictions, however, that can be disruptive to a large-scale integrated project. His other obligations, such as classwork, prevent full-time and year-round participation in a project. Not all project work is suitable for dissertation material, and various problems of proprietary and originality arise.

The manpower market has traditionally been limited to the graduate student. The current availability of recent (and not so recent) Ph.D.'s provides other options with advantages over the use of graduate student manpower. These include completed training, well-oriented interests, proven skills, full-time availability to participate, and greater self-direction. It can be further argued that post-doctoral contributors probably cost very little more than do graduate students. Double the salary of a graduate research assistantship, add the costs to the project of cultivating the talents of the student, plus the relatively high risk of failure on the student's part to find a dissertation project to his liking and you have most of the price of a recent Ph.D.

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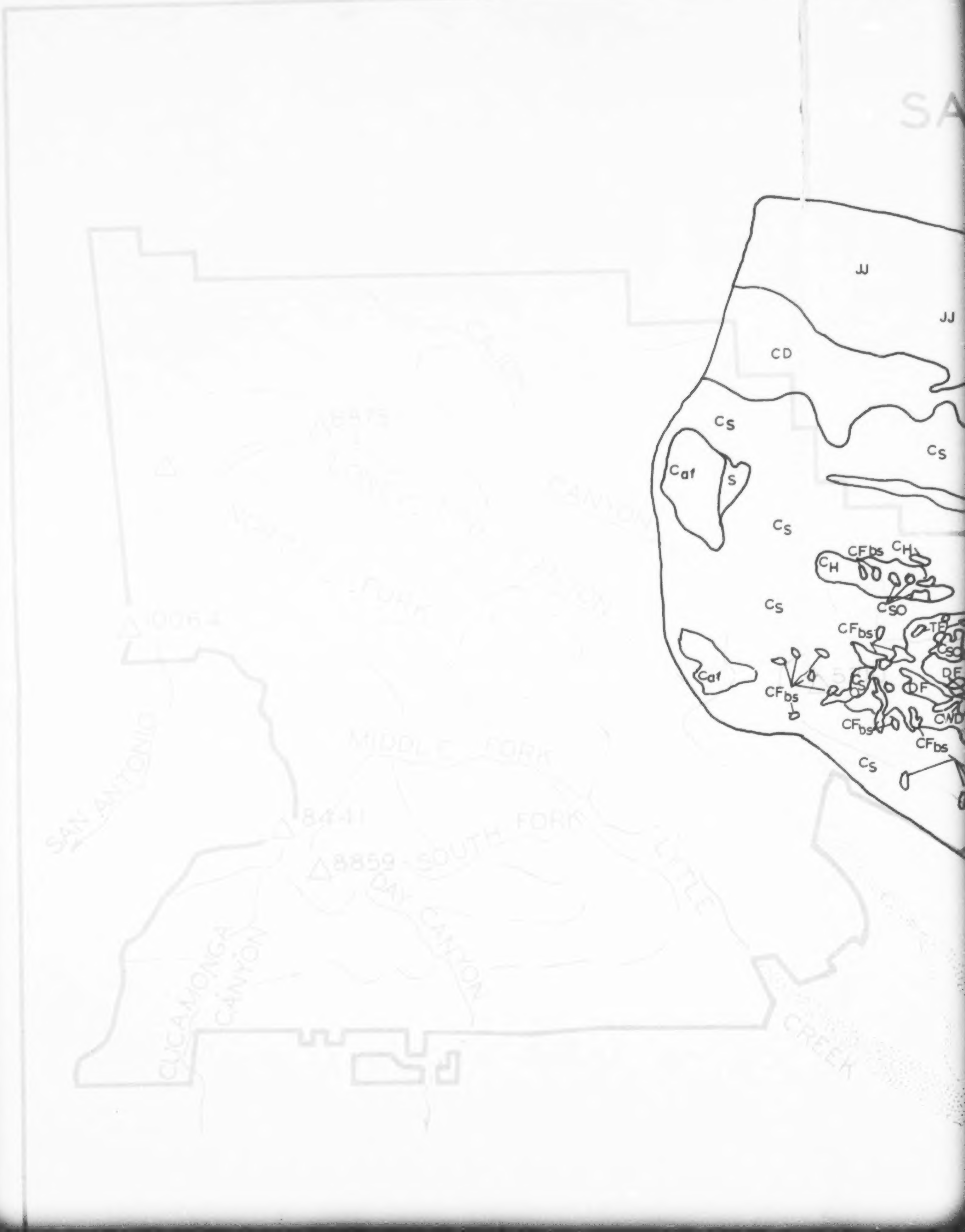

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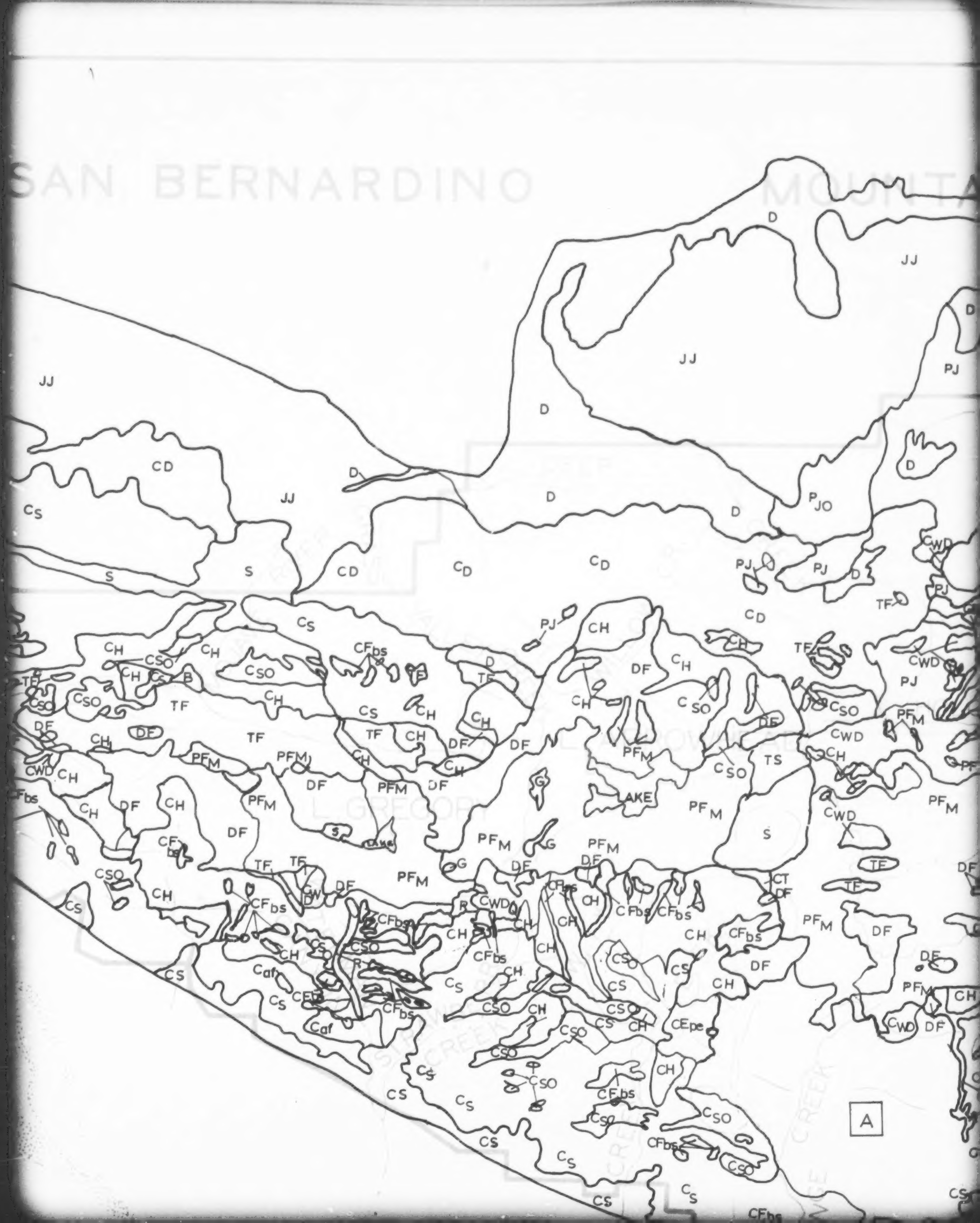
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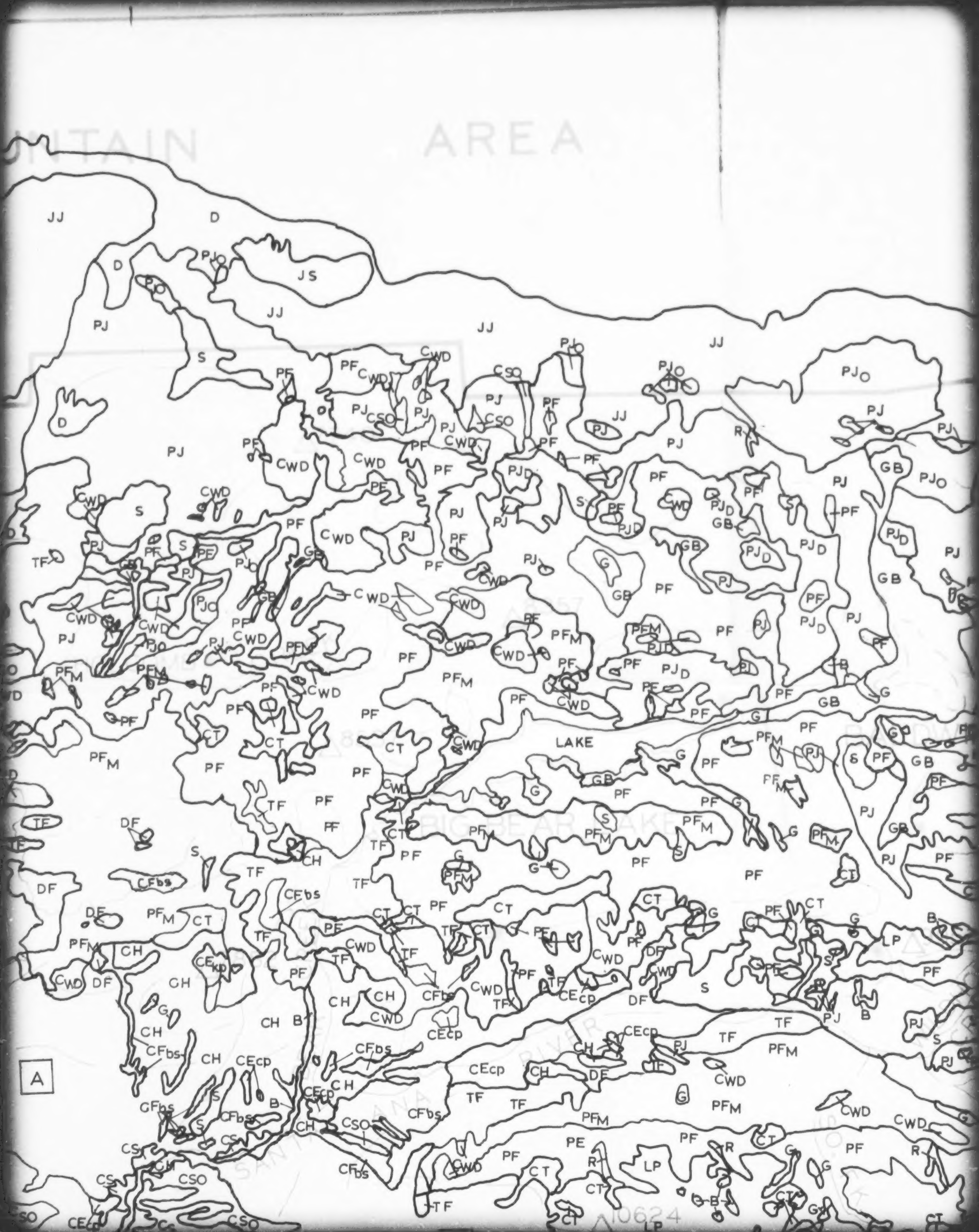
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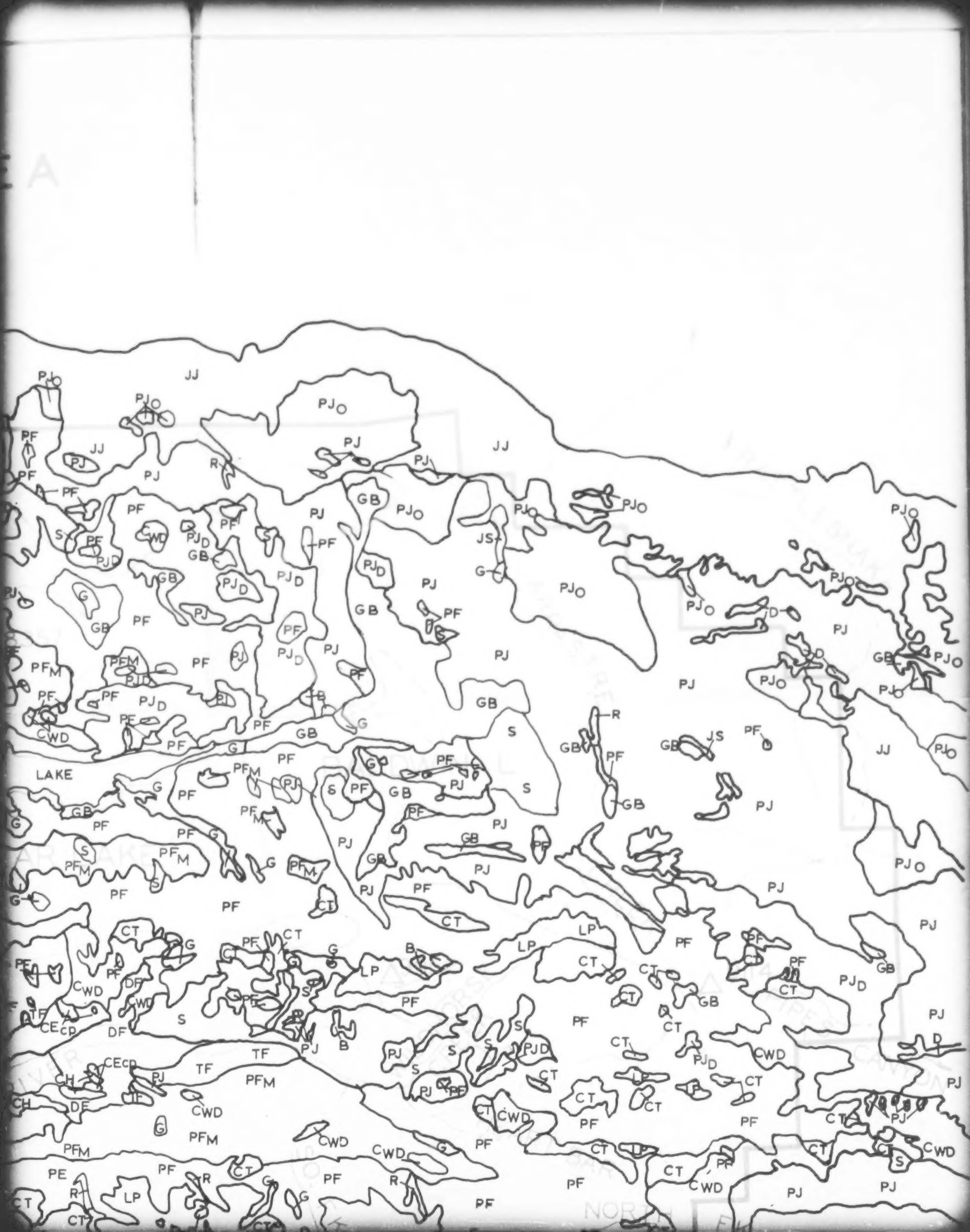

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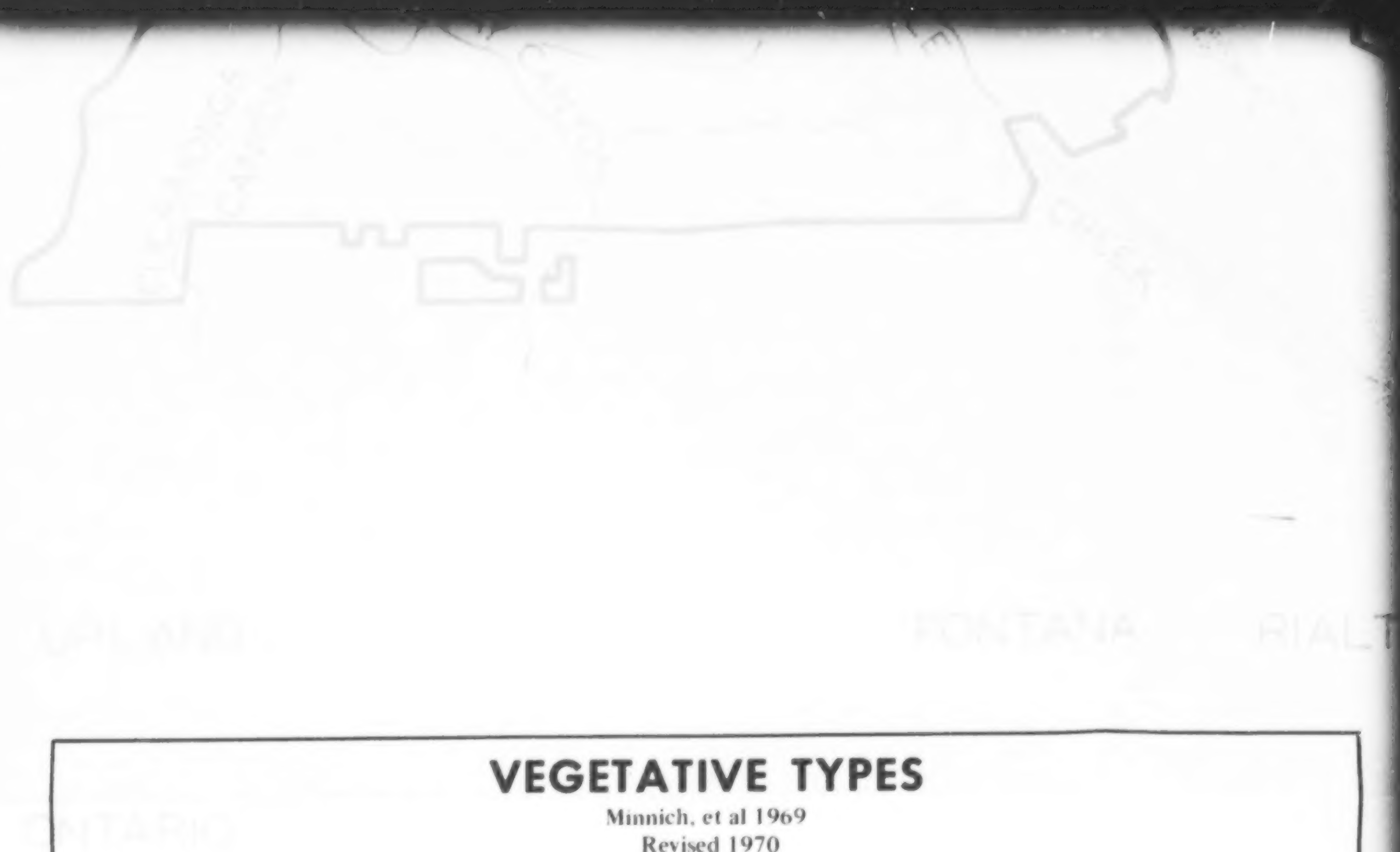


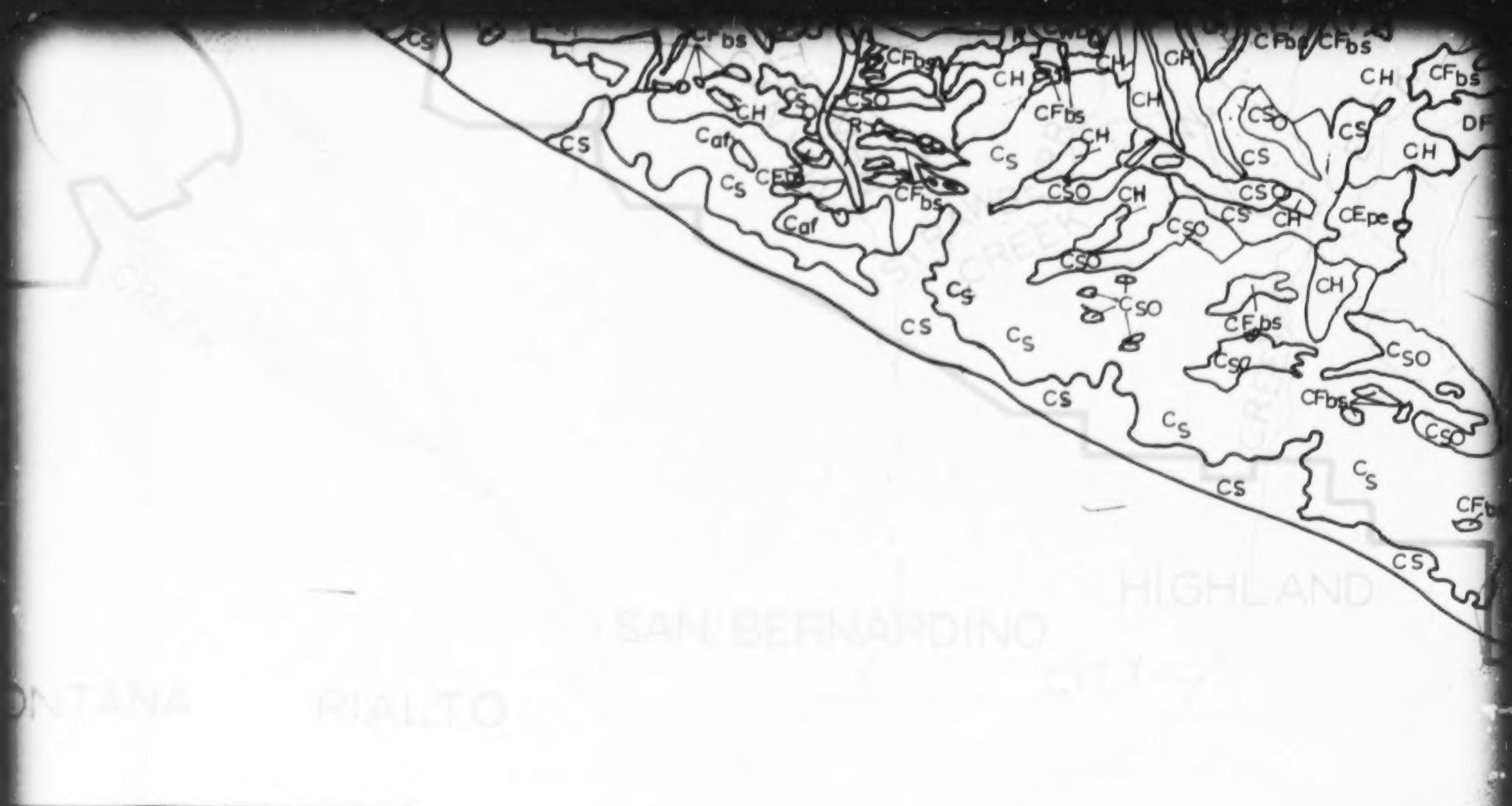
VEGETATIVE TYPES

Minnich, et al 1969
Revised 1970
LEGEND

Symbol	Name
Chaparral	
CS	Coastal Sage Scrub
C_s	Soft Chaparral
CH	Hard Chaparral
CSO	Scrub Oak Chaparral
CWD	Oak Woodland Emergent
CD	Desert Chaparral
Forest Emergents In Chaparral	
CFbs	Big-cone Douglas Fir
CEcp	Coulter Pine emergent in Chaparral
CEkp	Knobcone Pine emergent in Chaparral
Dry Forest	
DF	Coulter Pine - Black Oak
Montane Conifer Forest	
TF	Marginal Conifer
PF	Yellow Pine - White Fir
PFM	Mixed Yellow Pine - White Fir - Black Oak
CT	Timberland Chaparral

Symbol	Name
Sub - Alpine	
LP	Sub-Alpine Forest
Desert Woodland	
DW	Desert Woodland
PJ	Pinyon - Juniper
PJD	Dense Juniper - Mahogany
PJO	Open Pinyon - Juniper
GB	Great Basin Sagebrush
High Desert Vegetation	
DH	High Desert
JS	Joshua Tree
JJ	Juniper - Joshua Tree
D	Open Desert
Miscellaneous	
B	Barren
G	Grassland
R	Riverine
S	Sub - Climax

Figure A-2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Name

Sub-Alpine Forest

nd

Desert Woodland
Pinyon - Juniper
Dense Juniper - Mahogany
Open Pinyon - Juniper
Great Basin Sagebrush

egetation

High Desert
Joshua Tree
Juniper - Joshua Tree
Open Desert

Barren
Grassland
Riverine
Sub - Climax

CONGLOMERATION OF TYPES

A	B	C
B	R	B
CH	TF	S
CS	PF	DF
C_S	CT	PF
CP	CH	CH
CFbs	CS	CS
CSO	CSO	CSO
CEcp	CWD	CEcp
CWD	CEcp	TF
CEkp	PFM	CWD
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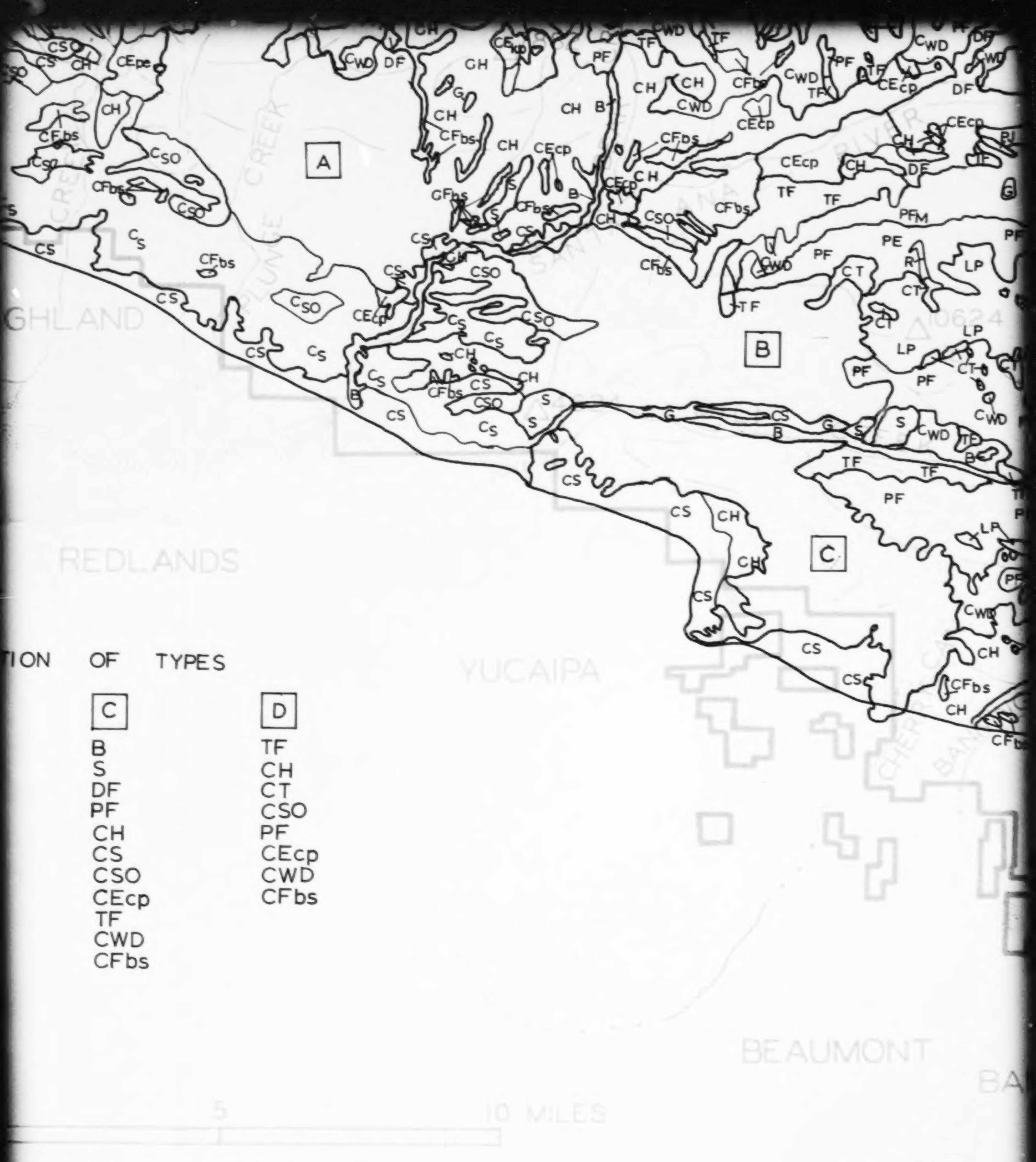
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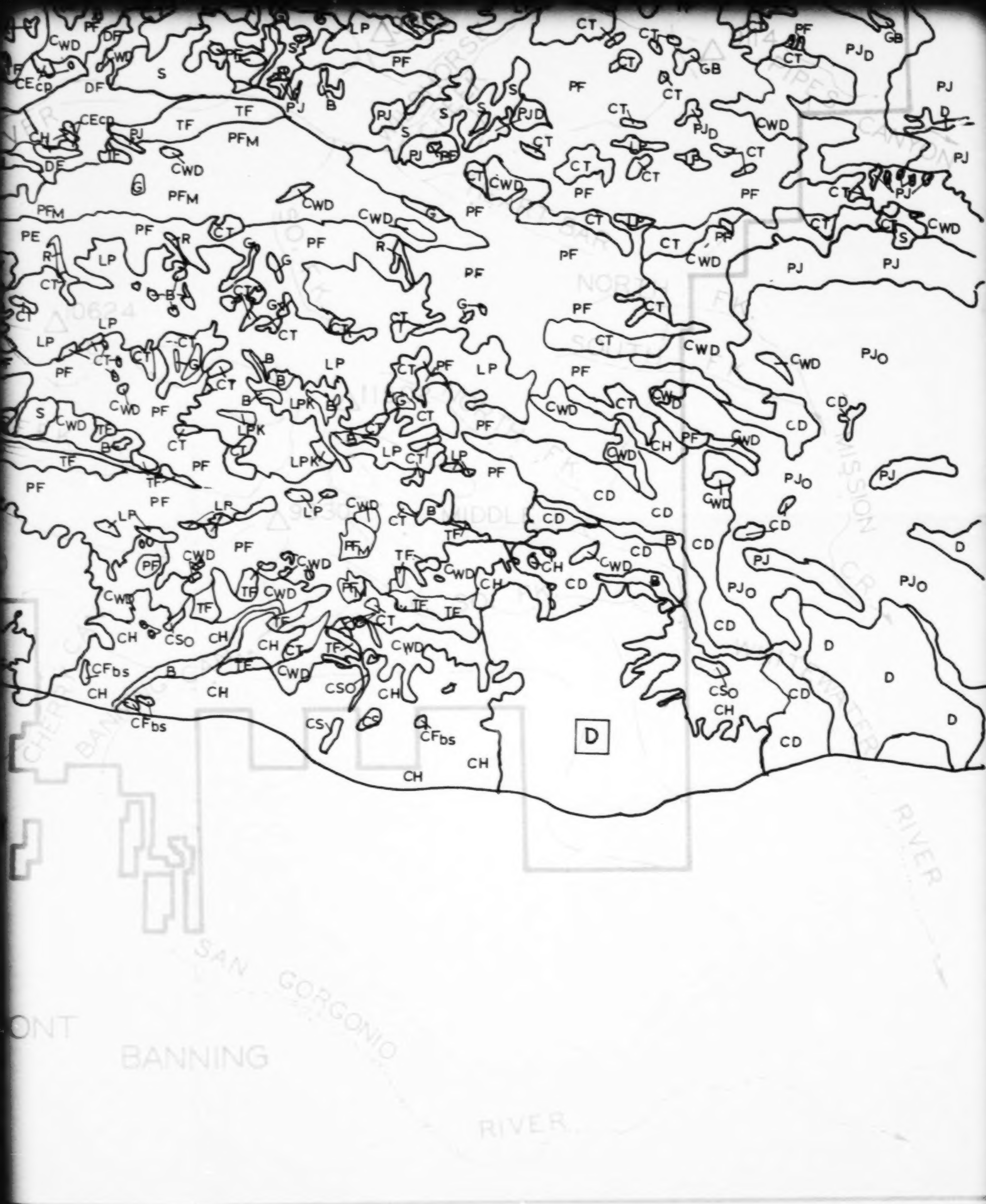
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